PiBS # 4913e

Deloro Mine Site Cleanup

Young's Creek Area Rehabilitation Alternatives

Final Report

Prepared for:

The Ontario Ministry of the Environment

Prepared by:

CH2MHILL

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Executive Summary

The Deloro Mine/Refinery Site, located in Eastern Ontario, began operation as a gold mine in the 1860s. Over the next 100 years, site activities also included the smelting and refining of a number of other elements including arsenic, silver, and cobalt. Activities associated with the mining, smelting and refining of metals ceased in the 1950s. These historical activities at the site have resulted in significant environmental impacts to the soil, groundwater, surface water and sediment quality both onsite and offsite.

Abandonment of the site by its owner(s) forced the Ontario Ministry of Environment (MOE) to take control of the property in 1979 and to initiate control measures to limit the environmental impact from the site. Remedial initiatives by the MOE have resulted in reductions of arsenic loadings to the Moira River. Arsenic loading to the Moira River has been reduced by more than 80 percent from an annual average of 52.1 kg/day in 1979 to an annual average of less than 10 kg/day since 1983.

To provide further treatment, and to mitigate any unacceptable impacts on human health and the environment, CH2M HILL Canada Limited (CH2M HILL, formerly CH2M Gore & Storrie Limited [CG&S]) was retained by the MOE to develop and implement a comprehensive rehabilitation program focusing on four individual areas of concern at the Deloro Mine Site. These areas included the Mine Area, the Industrial Area, the Tailings Area, and the Young's Creek Area. The purpose of this report is to identify and evaluate rehabilitation alternatives for the Young's Creek Area and to select a recommended alternative based on the evaluation. Young's Creek is located along the east part of the Deloro Mine Site and consists of an onsite and an offsite portion.

The sediments in the onsite portion of the Young's Creek Area (south of the east tailings dam and north of Highway 7) are contaminated to varying degrees with arsenic, cobalt, copper, and nickel compounds, as well as low-level radioactivity. The contamination is widespread within the upper 0.5-m of the red mud and organic sediments of the flood basin. The contamination extends deeper into the silty clay layer in the northern half of this area. The sediments in the offsite portion of Young's Creek (south of Highway 7 extending to the confluence with the Moira River) are also contaminated with arsenic and metals, albeit to a significantly lesser degree than the onsite sediments. Contamination in the offsite sediment is generally limited to the upper 0.5 m. Offsite, the underlying silty clay quality is comparable to that found in the Moira River watershed.

The source of sediment contamination both onsite and offsite has likely been the occasional historical releases and seepage from the Tailings Area impoundment. The contaminated sediments exceed the MOE's Severe Effect Level (SEL), which means there is potential for harmful impacts to the local aquatic and terrestrial ecosystems. A further hazard to human health is posed by the potential for re-mobilization of the contaminated sediments during flooding events, which will result in high contaminant loadings to the Moira River. In addition, the low-level radioactivity in the onsite portion of the Young's Creek Area may pose a human health or ecological hazard both as it exists in place as well as via suspended particulate from dried radioactive sediment.

The evaluation of sediment remediation alternatives was conducted in stages. The first stage was to identify a long list of conceptual remediation methods. The long list of conceptual remediation methods included:

- Shallow Excavation of Highly Contaminated Sediments and Disposal Onsite
- Shallow Excavation of Highly Contaminated Sediments and Onsite Treatment
- Deep Excavation of Highly Contaminated Sediments and Underlying Contaminated Silty Clay Soil and Disposal Onsite
- In-Place Capping of Contaminated Sediments
- Creek Rehabilitation
- Flow Diversion Away from Most Highly Contaminated Sediments
- Flow Regulation in the Contaminated Portion of the Young's Creek Area

These methods were screened early in the process to eliminate methods that would not be effective, would not comply with regulatory requirements, or that could not satisfy the design closure criteria for the site. Based on the results of the screening, the methods that were not rejected were either classified as primary remediation methods or enhancing protective features. Primary remediation methods are methods that have the ability to significantly reduce contaminant loading to the environment. Methods that cannot reduce contaminant loads alone but can be combined with the primary remediation alternatives to provide additional protection were retained as enhancing environmental features. Comprehensive remediation alternatives were then formed by combining primary remediation methods and enhancing protective features.

The comprehensive remediation alternatives were then screened a second time using the exclusionary criteria. This step was completed to ensure that the addition of an enhancing protective feature to a primary remediation method did not undermine that method's ability to mitigate risks to human health and the environment. The comprehensive remediation alternatives that satisfied the screening criteria a second time included:

- Shallow Excavation, Disposal Onsite, Creek Rehabilitation with optional enhancing features:
  - In-Place Capping
  - Flow Regulation
- Deep Excavation, Disposal Onsite, Creek Rehabilitation

These comprehensive remediation alternatives were then evaluated using detailed evaluation criteria that considered technical, cost, natural environment, and social factors. The onsite and offsite portions of the Young's Creek Area were evaluated separately due to significant differences in the onsite and offsite portions of Young's Creek (i.e. water depth, contaminant level, and property ownership).

The detailed evaluation resulted in the following recommended remediation alternative for the Young's Creek Area for onsite and offsite areas, respectively:

- Deep Excavation, Disposal Onsite, Creek Rehabilitation
- Shallow Excavation, Disposal Onsite, Creek Rehabilitation

This alternative will consist of the construction of a secure engineered onsite containment cell to store the wastes. Approximately 259,000 m^3 of contaminated sediments will require excavation and onsite disposal under this alternative. Sediment quality remaining following excavation will be equal to or better than that existing in the Moira River, Moira Lake, and Stoco Lake. Following excavation of the contaminated sediments, creek rehabilitation measures will be implemented that include construction of a perimeter wetland shelf and the installation of two strategically located wetland parcels.

Operation, maintenance and monitoring efforts under the recommended alternative will be associated primarily with the onsite secure containment cell. The pumps, controls, and piping associated with the leachate collection system will require monitoring and periodic maintenance. There will be hydro costs associated with the operation of the collection pumps that transfer the collected leachate to the treatment facility. Periodic maintenance of the cap will be required to repair any erosion damage. Environmental performance monitoring of the containment cell will be required, including leachate and groundwater monitoring. A detailed operations and maintenance plan should be established for the containment cell following implementation of this alternative.

The costs associated with this alternative include capital costs of $12,487,000 and annual operation and maintenance costs of $65,000. The net present value of this alternative assuming an effective interest rate of 5 percent and a planning horizon of 20 years is $13,337,000. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

Data gaps and issues that should be resolved prior to final design and implementation of this alternative include the following:

- The potential for using the lesser contaminated silty clay soils from the onsite portion of Young's Creek as part of the clay cap on the Tailings Area should be investigated further. Although placing these sediments in the Tailings Area is not required under this alternative, significant cost reductions could be realized if this was feasible.
- It should be confirmed with the Ministry of Natural Resources (MNR) that the approach taken under this alternative to restore the Young's Creek Area following excavation is both necessary and acceptable. It also should be confirmed with the MNR and the Conservation Authority that the required permits can be obtained to implement this alternative.
- Permission will be required from the property owners of the offsite portion of Young's Creek to implement the recommended alternative.
- An ecological risk assessment is planned to confirm that the deeper, less contaminated silty clay soils in the offsite portion of Young's Creek can remain in place without posing an unacceptable risk to ecological receptors. However, as stated in this report, previous studies in the Moira River have concluded that the levels of contamination that would remain in the sediments would not adversely impact benthic invertebrates or fish

populations in the Moira River, Moira Lake, and Stoco Lake. It is also recommended that an ecological risk assessment be completed for the onsite portion of Young's Creek to further investigate and quantify the risk associated with leaving the deeper less contaminated underlying silty clay soil in place.

- The absence of significant impacts on groundwater in the Young's Creek Area should be confirmed as part of the Closure Plan development.
- Floodplain modelling should be conducted to confirm that the proposed containment cell, and other changes to the floodplain, does not create flooding problems in the vicinity of Highway 7.
- The release of contaminants from the Tailings Area must be adequately addressed prior to undertaking remedial efforts in the Young's Creek Area.

The recommended alternative will be further developed in a subsequent report entitled Closure Plan for the Young's Creek Area. The Closure Plan will be the subject of additional public consultation and stakeholder review in addition to providing supporting documentation for regulatory reviews and applications. The comments will be incorporated into the final rehabilitation strategy and implemented in the construction phase of the project.

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1. Introduction

1.1 Background

Nearly a century of mining and industrial activity has resulted in significant environmental degradation of the Deloro Mine/Refinery site. Tailings and waste zones at the site contain up to 30 percent arsenic. Runoff and seepage from the various waste zones at the site have resulted in arsenic contamination of the Moira River, which flows through the site. Abandonment of this site by its owner(s) forced the Ontario Ministry of the Environment (MOE) to take custody of the property in 1979 and to initiate control measures to limit the environmental impact from the site.

CH2M HILL Canada Limited (CH2M HILL, formerly CH2M Gore & Storrie Limited [CG&S]) was retained by the MOE in April 1997 to develop and implement a comprehensive rehabilitation program for the closure of this former mine site. As part of this comprehensive rehabilitation program, CH2M HILL is developing remediation alternative plans for each of the four areas within the mine site's footprint, as shown in Figure 1-1. The limits of these four areas have been developed based on historical land use and waste disposal practices. The four areas include:

- The Industrial Area, where smelting and refining of the various ores were carried out
- The Tailings Area, where the by-products of the production phase were stored
- The Mine Areas, on both the east and west sides of the Moira River
- The Young's Creek Area, which has been impacted from historical releases from the Tailings Area

Closure plans will be developed for each of these four areas based on the closure objectives identified for the site in the report entitled *Deloro Mine Rehabilitation Project: Development of Closure Criteria, Final Report* (CG&S, 1998a) and the recommended rehabilitation alternatives developed for each area in the following reports:

- *Deloro Mine Site Cleanup – Industrial Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Tailings Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Mine Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Young's Creek Area Rehabilitation Alternatives*

1.2 Purpose of this Report

The overall objective of the Deloro Mine Site Cleanup is to successfully rehabilitate the mine site to mitigate, within reason, any unacceptable impacts on human health or the environment. As part of this overall objective, several area-specific objectives have been developed. Achieving these objectives, in conjunction with the other area-specific objectives, will aid in the successful rehabilitation of the Deloro Mine Site.

The alternatives reports summarize the previous investigations and reports that have been commissioned for the subject areas. Several alternatives that have been identified in previous reports are evaluated based on their environmental impacts. The criteria used to evaluate the impacts of alternatives reflect all components of the environment, including natural and social environmental impacts, as well as technical and cost considerations. The evaluation approach also recognizes the need to determine and assess "reasonable" remedial alternatives based on existing site information. The identification of remediation alternatives is not intended to be an exhaustive search for all conceivable or experimental remediation solutions that could be attempted. The recommended alternative for each of the four areas will meet the closure criteria established in the report entitled *Deloro Mine Rehabilitation Project: Development of Closure Criteria, Final Report* (CG&S, 1998a) and will be further developed in subsequent reports outlining closure plans for each of the areas.

1.3 Organization of Report

This report consists of seven sections, including the introduction. Section 2, Background and Problem Definition, describes the history of the site and a brief summary of the results of previous site investigations and studies within the subject area. The existing physical conditions of the subject area including additional background details are described in Section 3, including the nature and volume of the contaminated material. Section 4, Alternatives Evaluation Process, describes the process by which alternatives are generated and the approach to evaluation of the alternatives, as well as the closure objectives that must be met by the rehabilitation alternatives. Additional information pertaining to the detailed evaluation criteria is contained in Appendix A. Section 5, Development and Evaluation of Alternatives, establishes, describes and evaluates rehabilitation methods and alternatives. Section 6 provides the recommended remedial alternatives and cost opinion and identifies any data gaps that should be filled. Details associated with the opinion of cost information are contained in Appendix B. Section 7 lists the references used in the preparation of this report.

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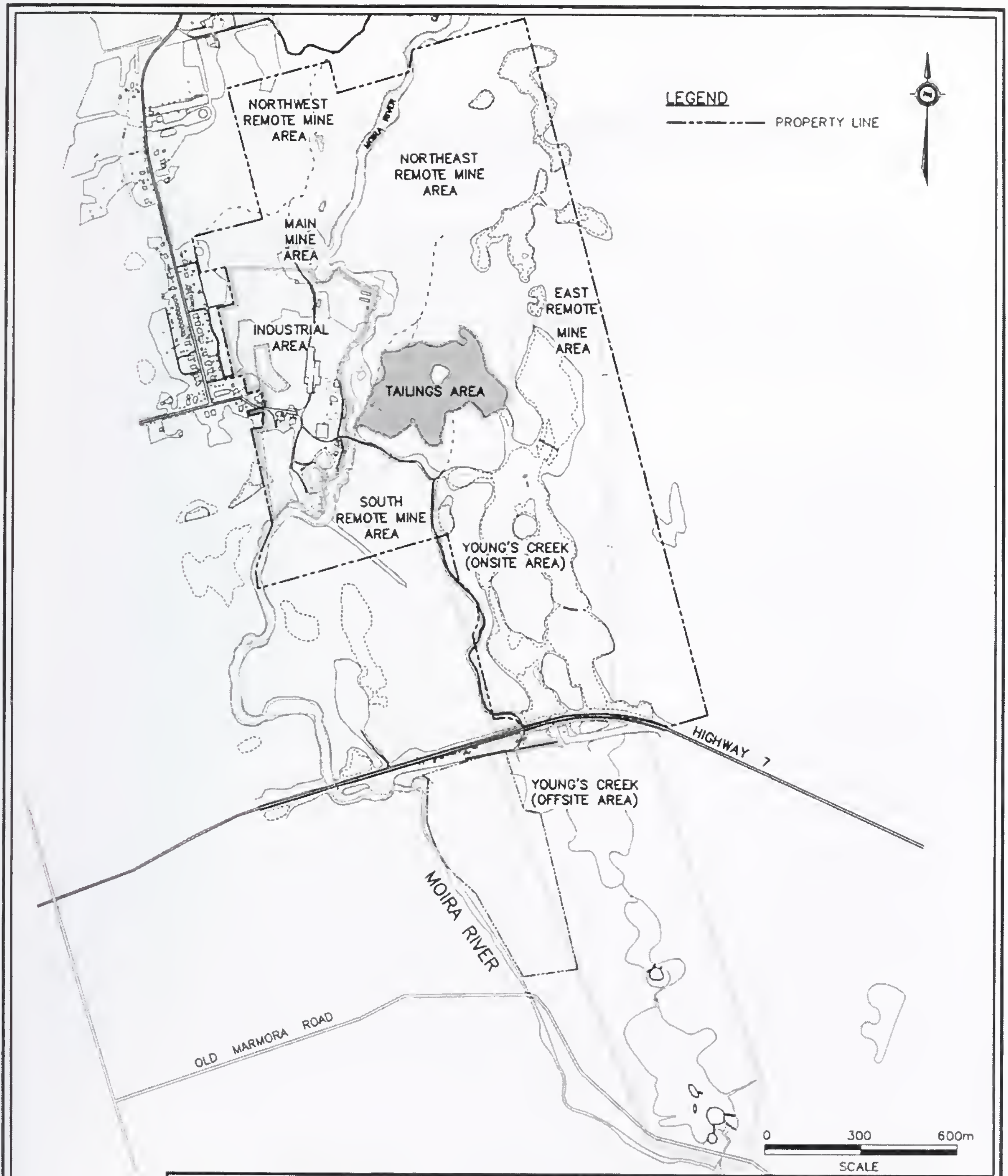

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FIGURE 1-1
DELORO MINE/REFINERY SITE SHOWING THE INDUSTRIAL, MINE, TAILINGS AND YOUNG'S CREEK AREAS
DELORO, ONTARIO

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2. Background and Problem Definition

This section provides a brief description of the history of the Deloro Mine Site and the Young's Creek Area and summarizes the previous investigations conducted within the Young's Creek Area. This section also clearly defines the problems to be mitigated as part of the recommended remediation alternative. A detailed description of the historical mining activities that have taken place at the Deloro Mine Site since the early 1860s is provided in the report entitled *An Historical Analysis of the Deloro Site* (Commonwealth Historic Resource Management Limited, January 1988).

2.1 Deloro Mine Site

The Deloro site, located in Eastern Ontario (see Figure 2-1, Site Location), began operation as a gold mine in the 1860s and evolved over the next century to mine and refine gold, as well as smelting and refining of a number of other elements including arsenic, silver and cobalt. It was the first plant in the world to produce cobalt commercially and was also a leading producer of stellite, a cobalt-chromium-tungsten alloy. Concentrates from uranium extraction were imported to the site and further processed to extract cobalt. Arsenic-based pesticides were produced from the by-products of smelting, which continued as a main activity at the site until the market collapsed in the late 1950s.

A century of handling hazardous materials and chemicals has resulted in significant environmental degradation of the Deloro Mine Site. Large quantities of refining slag, mine tailings, calcium arsenate, and arsenical pesticides remain at the site. Fuels, chemicals, and raw materials, such as sulphuric acid, coke, lime, soda ash, caustic soda, liquid chlorine, salt, scrap iron, sodium chlorate, and fuel oil, were handled at the site. Radioactive slag and tailings were produced as a result of the re-refining of by-products from uranium refining.

The Ontario government stepped in to take control of the site in 1979 due to failure of the owner to control environmental releases. The Ontario Ministry of the Environment (MOE) has been in care and control of the site since that time. Several rehabilitation actions have been implemented at the site to date that have significantly reduced releases from the site. In 1979, the annual average loading of arsenic to the Moira River was 52.1 kg/day. Since the arsenic treatment plant was put into operation in 1983, the arsenic loading to the river has been reduced by more than 80 percent, to an annual average of less than 10 kg/day. However, further work is required to reduce releases to acceptable levels and to secure the site for the long term. CH2M HILL Canada Limited (CH2M HILL) was retained in April 1997 to provide consulting engineering and project management services for the Deloro Mine Site Cleanup.

The former Deloro Mine Site is located along the banks of the Moira River on the eastern boundary of the Village of Deloro. The entire mine site, which includes the Industrial Area, Tailings Area, Mine Area, and the onsite portion of Young's Creek, is approximately 202 ha in area. The general boundaries of the onsite and offsite portions of Young's Creek in relation to the entire site are shown in Figure 1-1 in Section 1.

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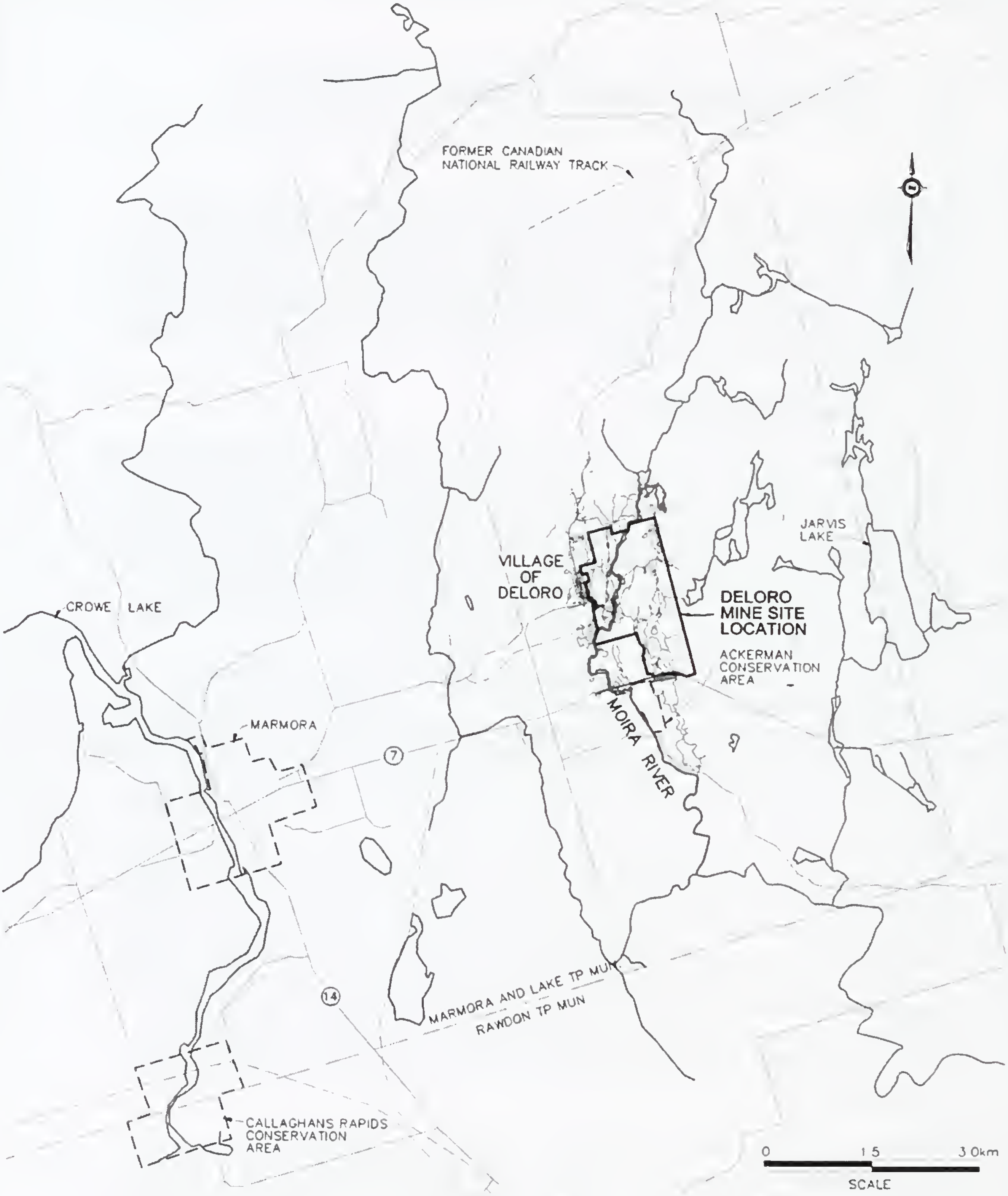
FORMER CANADIAN NATIONAL RAILWAY TRACK
VILLAGE OF DELORO
DELORO MINE SITE LOCATION
JARVIS LAKE
ACKERMAN CONSERVATION AREA
CROWE LAKE
MARMORA
7
MOIRA RIVER
14
MARMORA AND LAKE TP MUN
RAWDON TP MUN
CALLAGHANS RAPIDS CONSERVATION AREA
0
1.5
3.0km
SCALE

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FIGURE 2-1
DELORO MINE SITE LOCATION

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Access to the mine site is via Deloro Road, which intersects Highway 7 approximately four kilometres east of Marmora. The principal population centres in the area are the Villages of Deloro (pop. 180), Marmora (pop. 1,700) and Madoc (pop. 1,400). Marmora and Madoc are located approximately five kilometres southwest and ten kilometres east of the mine site, respectively.

2.2 Young's Creek Area

The Young's Creek Area consists of two areas referred to as the onsite and offsite portions of Young's Creek. The onsite portion of the Young's Creek Area is a 20-hectare (ha) area located north of Highway 7, east of both the Industrial Area and Tailings Area and bounded to the north, east, and west by the Mine Area. The offsite portion of the Young's Creek Area transects an area of approximately 1,620-m in length and is located between Highway 7 and the Moira River, south of the Deloro Mine Site. This portion of Young's Creek consists of three main beaver ponds that cover a combined area of approximately 19-ha. The ponds were formed primarily due to the presence of beaver and constructed dams in this area. Direct access to the onsite portion of the Young's Creek Area is available at the west boundary, where the creek intersects Highway 7. An adjacent dirt road off Highway 7 winds through the mine site and connects to the mine site entrance in the Village of Deloro. The offsite portion of Young's Creek can be accessed via Highway 7 at the north end of the offsite area and via Old Marmora Road to the west (See Figure 1-1).

The Tailings Area located at the northwest corner of the onsite portion of Young's Creek is predominantly comprised of the mine tailings impoundment. Due to continuous seepage of contaminated groundwater from the adjacent tailings impoundment, as well as periodic historical releases from the east tailings dam, areas of sediment within the Young's Creek Area have become contaminated beyond acceptable levels for aquatic and ecological habitats.

The predominant compounds that are present in the contaminated sediments are consistent with the chemical makeup of the tailings material (i.e. arsenic, cobalt, copper, nickel, and uranium). Since arsenic is present at the highest levels in most of the contaminated locations and since it is considered to be a highly toxic compound, it has been selected as the primary indicator of contamination for this report. Copper, cobalt, and nickel (in addition to arsenic) were also detected at elevated levels in the sediments in Young's Creek and also represent potential sources of contaminant loading to the Moira River and surrounding environment. A secondary indicator of impacts is the measurable radiation fields that originate from the presence of isotopic forms of uranium and cobalt. In addition, lead and silver were detected at elevated concentrations in the Moira River downstream of the site. Because of the presence of the contaminated sediments, Young's Creek has been designated a source of contamination to the Moira River and surrounding environment. Seven other metals, in addition to the ones identified here, have been identified as elevated in the onsite area of Young's Creek, but have not been retained as indicator metals due to the magnitude and frequency of exceedances for the metals described above. Figure 1-1 illustrates the location of the onsite and offsite portions of Young's Creek in relation to the Moira River and the Deloro Mine Site. Young's Creek flows into the Moira River, and it has been estimated that Young's Creek currently contributes approximately 3 percent (154 kg/yr) of the arsenic loading to the Moira River watershed, as described in the report entitled *Deloro Mine*

Rehabilitation Project – Development of a Sitewide Water and Load Balance, Final Report (CH2M HILL, March 2002). This estimation is based on the average measured water concentrations from the water quality monitoring stations located at Young's Creek/ Highway 7, Moira River/Highway 7, and downstream of the confluence of Moira River and Young's Creek, together with estimates of flow. This loading contribution is suspected to be primarily a result of the re-suspension of the highly contaminated sediment that occurs during high flow periods rather than the continuous seepage from the tailings impoundment.

2.3 Previous Investigations in the Young's Creek Area

Investigations and studies that have been carried out within Young's Creek are briefly described in the following paragraphs. Additional details are also provided in Section 3.

2.3.1 MOE (1986-1987)

The MOE produced a report describing the concentrations of selected inorganic parameters in soil and vegetation at, and adjacent to, the former Deloro Mine Site. A study was undertaken by the Phytotoxicology Section of the MOE's Standards Development Branch in 1986 and 1987 to assess the degree and extent of contamination of soils and vegetation by arsenic and other elements in the vicinity of the abandoned smelter complex (MOE, 1998). This involved sampling airborne dust (from 17 locations), surficial soil (from approximately 100 locations), and vegetation (from approximately 100 locations) within the Village of Deloro and across the former Deloro Mine Site. These samples were analyzed for 12 elements including arsenic, silver, molybdenum, manganese, nickel, lead, cadmium, cobalt, copper, iron, sodium, and zinc. Fourteen surficial soil samples were taken from the surrounding area to assess background conditions. Vegetation samples included native vegetation and those obtained from the gardens of Deloro residences. A soil bioassay was also conducted using soil obtained from nine locations.

These studies revealed that soil and vegetation from the Deloro Mine Site and some surrounding areas were contaminated with a number of chemical elements associated with past industrial activities. In Young's Creek specifically, the majority of the surficial soil samples yielded concentrations of arsenic and cobalt that exceeded the MOE Table A criteria for potable groundwater conditions (residential/parkland land use).[1] Of the remaining chemical elements, only copper and nickel were found in amounts greater than the criteria (from one sample).

2.3.2 SRK (July 1997)

In 1997, under contract to CH2M HILL, Steffen, Robertson & Kirsten (Canada) Inc. (SRK) performed a sediment survey of the western half of the Young's Creek Area, south of the east tailings dam and north of Highway 7. Thirty shallow boreholes were advanced to depths ranging from 0.5 to 1.2 m below ground surface (mbgs). Sediment samples were obtained for either chemical analysis (ICAP metals, arsenic, and anions) or stratigraphic documentation. The sediment survey identified the following three upper stratigraphic units (from surface to depth): upper organic material, reddish-orange mud, and grey sandy clay. The survey also indicated that this area was highly contaminated with arsenic, cobalt, copper, nickel, and uranium, and seven metals in addition to arsenic, cobalt, copper and nickel also exceeded either their applicable lowest effect level (LEL) for aquatic sediment quality[2] or the MOE Table A residential/parkland criteria for soil, where no sediment quality criteria exist. However, the metals mentioned first above were identified and retained as indicator metals in Young's Creek due to the frequency and magnitude of elevated concentrations across the site, and as field observations identified sediment, and not soil, conditions onsite at the time of the investigations. The additional metals will be evaluated as appropriate in the Site Specific Risk Assessment. The contamination was detected, to varying degrees and depths, throughout the west half of Young's Creek and was identified as a potential hazard to the downstream users and the environment.

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[1] Refers to the MOE *Guideline for Use at Contaminated Sites in Ontario*, February 1997, Table A – Soil remediation criteria for a potable groundwater condition.

2.3.3 SCIMUS (October 1997)

In 1997, as a result of the preliminary radiation survey performed on and around the Tailings Area, a supplemental investigation focusing on Young's Creek was commissioned. SCIMUS Inc., under contract to CH2M HILL, performed this survey, which involved the downhole gamma radiation logging of 50-cm-deep hand-augered boreholes. Fourteen boreholes were advanced along the western half of the Young's Creek Area with several more advanced along the eastern half. Select sediment samples from the western series of boreholes were submitted for laboratory analysis for radium and uranium.

The results of this survey indicated that a large portion of the western half of Young's Creek between the east tailings dam and immediately south of the large island outcrop was contaminated with radioactive tailings. Radiation fields up to 3 μSv/h were measured at surface and radium contents up to 100 Bq/g were measured in samples taken from a depth between 10 cm and 40 cm below ground surface (bgs). The radiation was limited vertically by the grey clay layer. The eastern half of the area as well as the western portion south of the large island outcrop registered radioactive fields that were indistinguishable from background.

2.3.4 CH2M HILL (August 1998)

In 1998, CH2M HILL implemented a field investigation to gather additional information on the physical and chemical properties of the red mud and the underlying clays and silts within the Young's Creek Area. The investigation was specifically targeted at determining the geotechnical properties of the contaminated sediments, the geochemical properties of the clay at 1.5 mbgs and the depth to the bedrock. The program involved advancing seven boreholes and conducting five bedrock soundings. Four silty clay soil samples were taken at depth from selected boreholes and submitted for geotechnical and chemical properties. Two additional red mud samples were taken and submitted for geotechnical properties.

The results of this geotechnical investigation confirmed the general upper stratigraphy identified in previous studies, as well as determined that the bedrock extends to a depth of 5 m in some locations. The lower silty clay units have sufficiently low permeabilities to be considered as a potential source of capping or cover material elsewhere onsite. The red mud material has poor geotechnical qualities and may pose a concern during consolidation. Additional chemical analysis indicated that arsenic, cobalt, copper, and nickel concentrations at a depth of 1.5 m are at or slightly exceed the MOE lowest effect level (LEL) for aquatic sediment quality (including the LEL for cobalt from the MOE's Open Water Disposal Guidelines[OWDG]). One sample at the 1.5-m depth exceeded the MOE Table A soil remediation criteria for cobalt for potable groundwater conditions.

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[2] Refers to *MOE Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario Lowest Effect Level (LEL) Criteria*, August 1993.

2.3.5 CH2M HILL (August 1998)

In 1998, CH2M HILL performed supplemental sediment sampling within the Young's Creek Area. This study focused on the eastern half of the area and involved advancing 13 shallow boreholes (less than 1.0 m deep) and 14 submerged sediment samples for chemical and stratigraphic information. As a result of these sampling efforts, 34 sediment samples were submitted to a laboratory for chemical analysis of arsenic, cobalt, copper, nickel, and uranium.

The results of this supplemental sediment survey indicated that the upper stratigraphy of the east half of the area is consistent with the three units identified within the west half. The stratigraphy is (from surface to depth): upper organic material, reddish-orange mud, and grey sandy clay. The chemical analysis indicated that the sediments within the east half were also contaminated with arsenic, cobalt, copper, nickel, and uranium, but generally to a lesser degree.

2.3.6 CH2M HILL (March 1999)

A trial excavation of the frozen sediments was conducted in March of 1999. The purpose of the investigation was to assess the feasibility of consolidating the impacted Young's Creek materials as a remediation strategy. As part of this investigation, five test pits were excavated, as near as possible to existing borehole locations from the geotechnical investigation, to compare results.

The results of the trial excavation identified the need for the red mud found in the northern portions of Young's Creek to be dried to address settlement concerns under a consolidation strategy. As it was determined that the ice offers a stable work platform, any excavation work in the Young's Creek Area should be conducted during the winter months to avoid the soft soils/sediments and high water tables that represent summer conditions. Impacted sediment marginally exceeding the MOE LEL for nickel and copper, as well as slightly exceeding the OWDG LEL for cobalt, was encountered at depth (i.e. bedrock) in several locations.

2.3.7 CH2M HILL (2000-2001)

CH2M HILL conducted an investigation of the sediment quality in the offsite section of Young's Creek in late 2000 and in early 2001. This investigation consisted of the identification and assessment of all beaver dams in Young's Creek, south of Highway 7, and evaluation of the extent and quality of sediments throughout the offsite section of Young's Creek to the confluence of Young's Creek and the Moira River (approximately 1.7 km).

During the offsite investigation, CH2M HILL collected 142 discrete samples (including duplicates) from 55 locations, in order to evaluate the extent and quality of sediments and underlying clay/silt deposits. The majority of these samples consisted of sediments (organic silts) and underlying clays and silts from the three beaver ponds, as well as several fringe sediment samples collected immediately adjacent to the ponds. All samples were analyzed for the presence of arsenic, nickel, copper, cobalt, uranium, lead, and silver. The first five parameters listed were selected based on the contaminants of concern identified by CH2M HILL in the same media during the onsite investigations of the Young's Creek Area. In addition, the other two metals (lead and silver) that were analyzed by Golder Associates/Global Tox International during the Phase II Moira River Study (Golder, 2001), were also included. While it was identified in previous reports that seven metals in addition to those mentioned above were present at concentrations greater than their respective LELs or MOE Table A criteria, arsenic, nickel, copper, cobalt, uranium, lead, and silver were identified and retained as indicator metals in Young's Creek. This was due to the frequency and magnitude of elevated concentrations across the site and as field observations identified sediment, and not soil, conditions onsite at the time of the investigations. The seven additional metals will be evaluated as appropriate in the Site Specific Risk Assessment.

The general stratigraphy encountered in the offsite portion of Young's Creek consisted of three principal units including:

- Dark brown to black organic silt material
- Upper silty clay unit
- Lower silty clay unit

The sampling results revealed that arsenic, copper, cobalt, and nickel were detected at the highest concentrations in the upper organic sediment unit, where concentrations for the majority of samples exceeded the MOE severe effect level (SEL) criteria or the lowest effect level (LEL) criteria for aquatic sediment quality[3](including the OWDG LEL for cobalt). Concentrations declined with depth in the silty clay units located beneath the upper organic sediment. Concentrations for the constituents of concern within the upper silty clay unit generally varied between less than the MOE LEL sediment quality criterion to greater than the MOE SEL sediment quality criteria. The concentrations in the lower silty clay unit above bedrock typically slightly exceeded or were less than the MOE LEL sediment quality criteria.

Comparison of the subject concentrations in the lower silty clay unit with typical background soil concentrations in Ontario (MOE's Table F in the *Guideline for Use at Contaminated Sites in Ontario)* show that these concentrations, in most cases, are often representative of background levels and are likely not from contaminants derived from the onsite source. As such, the values detected in the lower silty clay unit are not considered significant based on a comparison to typical Ontario background concentrations and local onsite background levels. In most cases concentrations for the constituents of interest are equal to or better than the sediment quality downstream from the Deloro site in the Moira River and Moira and Stoco Lakes. The MOE background sediment concentrations, which are based on the analyses of the Great Lakes pre-colonial sediment horizon, also fall within the aforementioned ranges used in comparison.[4]

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[3] Refers to MOE *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario Severe Effect Level (SEL) and Lowest Effect Level (LEL) Criteria*, August 1993.

Arsenic and metal concentrations in sediments from the onsite and offsite portion of Young's Creek were compared. The results indicated that although arsenic and metal concentrations are still elevated in the offsite portion of Young's Creek, the concentrations in both the organic sediment unit and the upper silty clay unit are in most cases anywhere from 1.4 to 75 times lower than the maximum corresponding onsite concentrations.

In summary, the three beaver ponds in the offsite portion of Young's Creek have, in effect, acted as sediment collection basins for contaminated sediments that originated upstream from the onsite Young's Creek Area. This has resulted in the reduction of the sediment load to the Moira River from Young's Creek. However, the offsite section of Young's Creek has become extensively contaminated and there is a risk that contaminated sediments could be released to the Moira River following the failure of beaver dams or during a major flood event. To assist in minimizing the potential for this, the MOE have established water level control measures in Young's Creek to minimize the chance of a major breach in the beaver dams.

2.4 Problem Definition

The Young's Creek Area has been identified as a contributing source of contamination within the Moira River watershed. The sediment in the Young's Creek Area contains varying levels of primary indicator metals arsenic, cobalt, copper, nickel, and, for the onsite portion, low levels of radiation. In addition to the ongoing loading to the Moira River, in their current state, these sediments pose a potentially greater hazard via re-suspension of the sediment during flooding events.

In order to mitigate these detrimental impacts to the environment, a remedial solution that reduces or eliminates these impacts must be implemented. Several potential options have been put forth. These options will be evaluated based on their application to the existing conditions within the Young's Creek Area. The existing conditions are discussed in the following section.

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[4] Refers to MOE *Guideline for the Protection and Management of Aquatic Sediment Quality in Ontario* Table 4 Background Levels for Metals, August 1993.

3. Existing Conditions

This section focuses on describing the existing site and environmental conditions within the onsite and offsite portions of the Young's Creek Area. It provides descriptions of the physical setting, the natural environment, and the social conditions of the Deloro Mine Site and the Young's Creek Area. This information forms the basis for identifying and evaluating viable remedial alternatives.

3.1 Operations

Current operations within the Young's Creek Area include the following:

- Monitoring Moira River and Young's Creek water quality
- Site security (onsite portion of Young's Creek)
- Monitoring condition of Beaver Dams in onsite and offsite portions of Young's Creek
- Removal of contaminants

3.1.1 Location and Access

Details related to location and access associated with the Deloro Mine Site and the onsite and offsite portions of Young's Creek were provided previously in Sections 2.1 and 2.2. The general boundaries of the onsite and offsite portions of Young's Creek in relation to the entire site are shown in Figure 1-1 in Section 1.

3.2 Physical Setting

This section will outline the physical characteristics that will form a part of the final rehabilitation strategy for the Deloro Mine Site.

3.2.1 Climate

The Deloro area and surrounding region receives an average yearly precipitation of 889-mm (Environment Canada, 1990). Maximum precipitation usually occurs in the month of September, with approximately 80 to 100 mm of rain. The spring growing season of April, May and June accounts for about one quarter of the annual precipitation. The months of September, October, and November account for about one quarter of all precipitation, either as rain or snow.

The spring to fall average mean temperature is 16.9°C. The winter mean temperature is -7.4°C. The daily minimum average temperature for January and February is -13.4°C and the daily maximum highs average 25.3°C for the June to August period. The minimum and maximum average temperatures result in a maximum annual range in temperature of approximately 38.7°C. The record high was recorded in the summer of 1988, when temperatures exceeded 40.6°C over a 7-day period. The record low for the area is -40°C. Wind directions from November to March prevail from the west and in the spring and summer months wind directions prevail from the southwest.

3.2.2 Topography

The majority of the onsite portion of the Young's Creek drainage system is located within the mine site property. The Young's Creek Area is established in a topographic depression created by low bedrock scarps and outcrops that flank the creek to the east and west. The creek enters the property at the northeast corner and flows along the east side of the tailings impoundment, after which it splits into two wide, separate floodplain channels (i.e., east and west arms). The removal of beaver dams along the creek resulted in a considerable decrease in water levels, particularly in the west arm where the creek has been reduced to a narrow trickle. The creek leaves the property near Highway 7 (CG&S, October 1998b). Figure 3-1 presents a general site map showing both the onsite and offsite portions of Young's Creek.

The offsite portion of Young's Creek transects an area of approximately 1,620-m in length, and is located between Highway 7 and the Moira River, south of the Deloro Mine Site, as shown on Figure 3-1. This portion of Young's Creek consists of three main beaver ponds that cover a combined area of approximately 19-ha and that were formed by constructed and beaver dams in this area.

While detailed topographic mapping is not currently available, observations of the intervening channels between the ponds and between the Southern Pond and the Moira River indicate these channels are typically characterized by steep gradients with rock and boulder strewn beds. As a result, the channels have retained little or no sediment, but significant volumes of sediment are present within the three ponds. The area surrounding the ponds typically consists of steep, rugged terrain – particularly on the eastern side – and contains boulders and bedrock outcrops with sparse soil cover. The area near the Southern Pond in the vicinity of Old Marmora Road contains flatter terrain. A detailed site plan showing the overall configuration of the ponds including the approximate location of the beaver dams noted during the completion of this study is shown on Figure 3-1. All three ponds have a combined surface area of approximately 188,550 m^2.

Between the three main beaver ponds, water flows at a significantly higher velocity in well-defined channels up to approximately 2 m wide. Surface water elevations drop in the range of 3.0 to 4.5 m between each pond. Similarly, meandering channel flow also occurs through a swampy area for about 170 m between the southern dam and the confluence of the Moira River.

3.2.3 Geologic Setting

The general geologic setting involves the mine site being located at the contact between Precambrian basement rocks and overlying Palaeozoic sedimentary rocks. Bedrock is exposed primarily at the north end of the site and along the Moira River. An island outcrops within the Young's Creek Area north of Highway 7. Natural overburden, fluvial sediment, clay fill, building rubble, tailings, slag, or a mixture of all of these covers the bedrock over much of the site. The natural overburden consists primarily of silty clay with minor amounts of silty sand and peat; these native soils are generally found in areas of low topography.

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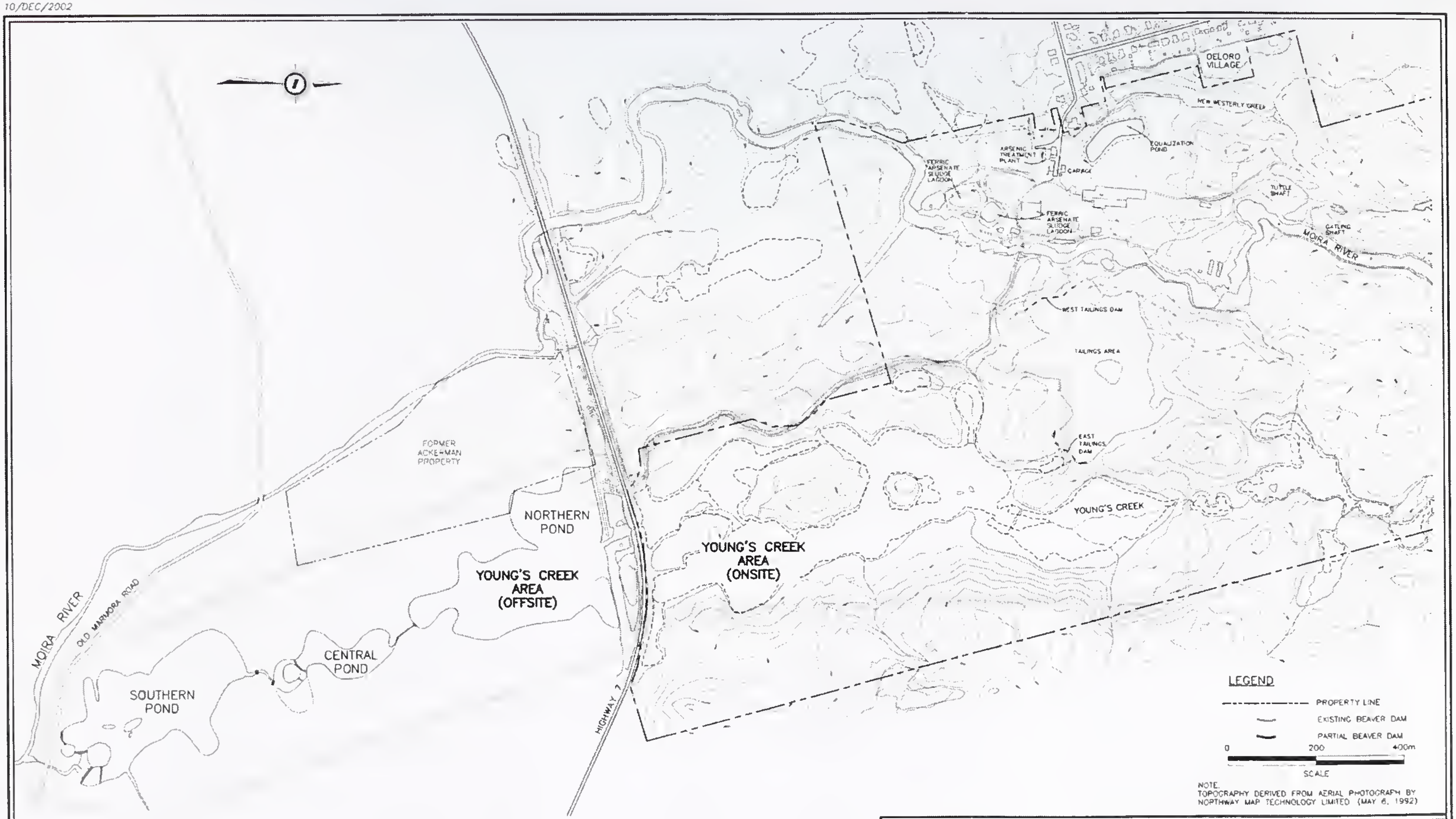

CH2MHILL

PROJECT No 119548

REHABILITATION OF THE OELORO MINE/REFINERY SITE

FIGURE 3-1
YOUNG'S CREEK SITE MAP
ONSITE AND OFFSITE AREAS

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Bedrock Geology

Precambrian metasedimentary and metavolcanic rock forms the bedrock beneath most of the site except for the western edge and eastern portions of the property. The western edge of the property is underlain by Palaeozoic limestones and shale, while the eastern portion of the property is underlain by the Deloro Pluton – a felsic intrusive ranging from granitic to syenitic in composition (Chapman and Putnam, 1984). The syenitic phase of intrusion is more prevalent in the southern half of the Deloro Pluton. A few Skarn lenses occur within 300 m northwest and southwest of the major mine shafts. Granitic phases include syenite, granite, and diorite. The granite is typically pink, massive, medium-grained, and well jointed. The bedrock generally has a northwesterly strike and dips steeply. Joint orientations in the rock trend northeasterly and northwesterly.

Some areas of exposed outcrops with the Young's Creek Area are identified on Figure 3-1 as island outcrops. In the Young's Creek Area, three island outcrops are present south of the east tailings dam. These outcrops provide the division of Young's Creek into the east and west arms. The largest of the three outcrops provides an ideal location for the frequent erection of beaver dams between the island and the east and west banks of the Young's Creek Area. The bedrock beneath the rest of the Young's Creek Area lies between two and five metres beneath the ground surface (CG&S, October 1998b). In the offsite portion of Young's Creek, bedrock outcrops along the eastern and western edge of the Northern Pond and becomes less evident towards the confluence of Young's Creek and the Moira River.

Sediment Stratigraphy – Onsite Portion of Young's Creek

Based on the observations from sediment sampling conducted within the onsite portion of Young's Creek (CH2M HILL, May 2001), the following general sequence of overburden stratigraphy has been identified:

• Dark brown to black organic material	(approximately 0 to 0.2 mbgs)
• Reddish-orange mud (discontinuous)	(approximately 0 to 0.7 mbgs)
• Grey sandy to silty clay	(approximately 0.2 to 1.2 mbgs)

The pattern of stratigraphy is variable with increasing distance downstream and east of the Tailings Area. The organic unit is usually encountered at the surface at most of the sampling locations. The reddish-orange mud was typically encountered below, and at some locations between, deposits of the organic material. Adjacent to two of the former beaver dams, and near the east tailings dam, the red mud is exposed at the ground surface. Presumably, the former beaver dams acted as hydraulic impoundments along the channel and promoted deposition of the mud. With increasing distance from the east tailings dam the presence and overall thickness of the reddish-orange mud layer diminishes.

A brief description of each of the overburden units in the onsite portion of Young's Creek is provided below.

Dark Brown to Black Organic Material. This unit consists of humus, rootlets, woody debris, grasses, and other decaying organic matter, with occasional pockets of silt and fine sand within the matrix. This material is typically moist to wet and soft, but is occasionally saturated where it underlies the reddish-orange mud layer.

Reddish-Orange Mud. This material consists of very fine-grained (i.e. clay-sized) bright red to reddish-orange mud that is consistently wet to saturated, and soft to very soft in density. The material is typically well to uniformly sorted, but sometimes shows evidence of gritty clastic matter.

Grey Sandy to Silty Clay. Grey sandy to silty clay, occasionally appearing as brownish-gray in colour near contact with overlying organic material, was encountered in each of the boreholes. This unit was typically observed as a fine sandy clay, with sand content increasing with depth. Density ranged from firm to hard, with greatest densities observed toward the maximum depth of each borehole. The unit was mainly subvertically fissured and fractured. Tan to brown oxidized zones were noted along fractures. Collected samples were moist to saturated. Medium sand and subangular gravel seams were occasionally encountered beyond approximately 0.7 mbgs. Large cobbles or possibly boulders/bedrock were also encountered in some boreholes, which is indicative of glacial till.

Sediment Stratigraphy – Offsite Portion of Young's Creek

Stratigraphy. Overall, observations from the sediment sampling locations (cores) show the following general sequence of overburden stratigraphy based on the typical termination depth for each stratigraphic unit expressed as metres below pond bottom (mbpb):

Description	Depth Range (metres below pond bottom [mbpb])	Average Thickness (m)
• Dark brown to black organic silt material	0-2.0	0.3
• Upper Silty Clay Unit	0.2 – 3.6*	0.36
• Lower Silty Clay Unit	0.6 – 2.5	0.25

*Anomalously deep termination depth for upper silty clay. Average termination depth is approximately 0.9 mbpb.

The general stratigraphy described above represents the range of termination depths observed for each stratigraphic unit. However, the stratigraphy between sampling points was variable with the termination depths for each unit varying between sampling locations. The depth of the organic sediment unit generally ranged between 0 and 2.0 metres below pond bottom (mbpb) with an average thickness of approximately 0.3 m. The depth of the upper silty clay unit ranged between 0.2 mbpb to 3.6 mbpb with an average thickness of approximately 0.36 m. The depth of the lower silty clay unit ranged between 0.6 mbpb and 2.5 mbpb with an average thickness of approximately 0.25 m. The termination depth of 3.6 mbpb for one sample from the upper silty clay unit at sample location 2029 is considered to be anomalously deep, as the average termination depth for this unit is approximately 0.9 mbpb.

The thickness of the organic sediment unit was variable between the ponds and was generally thickest in the centres of the ponds and at locations adjacent to beaver dams and where depressions exist in the pond bottoms. The organic sediment unit was encountered starting at 0 mbpb at most of the sampling locations. The sediment thickness decreased towards the edges of the ponds and was noted to be thickest in Central and Northern

Ponds. Over 1 m of organic sediment is present in the middle of the northern half of the Central Pond, while in the Northern Pond, over 2 m of organic sediments are present adjacent to the beaver dam at the south end of the pond. The organic sediment unit is generally thinnest in the Southern Pond, where only 0.7 m of organic sediment is present in the deepest portion of the pond near the centre.

Presumably, the existing and former beaver dams acted as hydraulic impoundments along the channel and promoted deposition of the sediments.

The upper and lower silty clay units exhibit a similar distribution pattern with respect to thickness with some variations. The thickness of the silty clay unit is greatest in the Central and Southern Ponds, where depths of up to 2.0 m and 1.5 m respectively were recorded.

A descriptive summary of each of the above overburden units in the offsite portion of Young's Creek is provided below.

Dark Brown to Black Organic Sediment Material. This unit consisted of humus, rootlets, woody debris, grasses, and other decaying organic matter. At some of the sampling locations some silt and fine sand was noted in the matrix. This material was typically wet to saturated and soft.

Upper Silty Clay Unit. This material was observed as very fine-grained light grey silty clay with occasional fine-grained sand, trace oxidation spots and pyrite flecs. The material was sometimes observed to be brownish-grey in colour near contact with overlying organic material. The upper silty clay material was consistently moist to wet and firm to very firm in density, becoming harder with depth. This material was typically well to uniformly sorted.

Lower Silty Clay Unit. This unit was very similar to the upper silty clay unit with some differences noted with respect to density and moisture content. This unit was typically observed as a fine-grained light grey silty clay material. Density ranged from firm to hard, with greatest densities observed toward the maximum depth of each sampling location. Collected samples were damp to wet. Large cobbles or possibly boulders/bedrock were also encountered in some boreholes, which is indicative of glacial till.

Although minor variations exist in the descriptions of the various stratigraphic units between the onsite and offsite portions of Young's Creek, as discussed above, in general, the stratigraphy between the two areas is very similar. One exception is the presence of reddish-orange mud material noted in the onsite portion of Young's Creek near the Tailings Area. This reddish-orange mud was not noted in the offsite portion of Young's Creek. In general the stratigraphy for both the onsite and offsite portions of Young's Creek can be classified as one of two principal units. The first unit consists of the dark brown to black organic sediment material commonly referred to as organic sediments. The second unit is the lower underlying silty clay soils. As discussed later in this section, in general, the most heavily impacted materials for both the onsite and offsite portions of Young's Creek exist in the upper organic sediment unit. Contaminant concentrations decreased with depth in the underlying silty clay soils.

3.2.4 Hydrogeology

The potential for impacts to groundwater associated with the contaminated sediments in the Young's Creek Area is considered to be relatively low given the low permeability of the underlying silty clay soils. In addition, it is also anticipated that there is limited potential for migration of contaminants via groundwater and, as such, limited hydrogeologic data has been collected.

Based on the geomorphology, the Young's Creek Area is commonly referred to as an underfit stream (i.e. a post-glacial stream discharge is a fraction of what occurred before and during glacial activity). The formation of the stream left low rock scarps and channel walls on the outermost east and west flanks, and a channel that occupies only a small, meandering fraction of the entire floodplain. The bottom of the Young's Creek basin is rock lined with a thin veneer of silty clay material overlain by the very permeable alluvial organic silt material (*sediment*) and fine sands.

Most of the shallow alluvial sediment material in the onsite portion of the creek is seasonally flooded, causing the uppermost part of the overburden profile (i.e. the permeable silts) to become saturated. Infiltration into the clay till, however, is restricted because of:

- The low saturated hydraulic conductivity of the silty clay material
- The very slight horizontal gradient (slope) of the Young's Creek Area towards Highway 7
- The poor drainage efficiency of the Young's Creek channel. (The creek channel includes almost no gullies, rills, or similar tributaries within the flat wide floodplain and is cut so shallow into the overburden that it stops where the silty clay unit begins.)

As a result of these restrictions, most of the Young's Creek channel flow in the onsite portion occurs during excess flooding, and from baseflow contributions from the upper organic sediment layer. Likely this has resulted in a very weak (i.e. low) horizontal hydraulic gradient along most of the Young's Creek channel, which captures shallow groundwater flow in the alluvial silt for a few metres on either side of the channel. It is also likely that shallow groundwater is not being vertically drained by the channel, but instead, it is slowly drained into pockets of deeper till and overburden that have been created by changes in the underlying bedrock topography. In the offsite portion of Young's Creek, the hydraulic flow is largely influenced by a series of beaver dams that form three main ponds, as previously described. The creek water depth is significantly greater in the offsite portion of Young's Creek than in the onsite portion and flows at a significantly higher velocity in well-defined channels up to approximately 2 m wide.

Finally, regionally and within the bedrock, groundwater flow is most likely to the south to southwest, as part of the flow determined by the topographically deeper basin formed by the Moira River.

3.2.5 Hydrology

The Young's Creek Area is within a small sub-catchment area located east of the Moira River. The creek originates in an area of low topography just south and east of the Deloro Dam and Reservoir, and flows in a southerly direction. It is characterized as a meandering to braided stream channel in the upper 0.5 m of alluvial-deposit organic sediment (silt) material. The pattern of flow and fluvial deposition is influenced by factors including active and inactive beaver dams, emergent and stabilizing vegetation in mid-channel bars and islands, available sediment supply, and the intensity of inter-annual floods. The creek flows beneath Highway 7 into the three main ponds previously described and through a bridge culvert at Old Marmora Road before discharging into the Moira River approximately two kilometres south of Highway 7 (CG&S, October 1998b).

3.2.6 Floodplain Mapping

Floodplain mapping was performed for relevant areas (e.g. potentially impacted areas) in both the Moira River and the onsite portion of the Young's Creek watershed sub-catchments (CG&S, November 1998). Floodplain mapping was not completed for the offsite portion of Young's Creek as part of the above noted study. In general it could be expected that similar flood effects would also occur in the offsite portion of the creek with some variations resulting from the steeper gradients in the Young's Creek channel, the influence of the beaver dams, and the influence of the bridge culvert under Highway 7. The floodplain elevations were generated using the hydrologic model BOSS HEC-2™, a water-surface profile computation program. This program is widely used in the field of floodplain management.

In accordance with the Ontario Ministry of Natural Resources guidance documents, the Zone 2 regulatory flood level for the 100-year flood was modelled. Due to the lack of storm flow data for Young's Creek Area, floodplain mapping for this sub-catchment was based on the assumption that the 100-year flow would not exceed 30 percent of the 100-year storm flow for the Moira River. Floodplain mapping was performed for the following flows:

10 percent of the 100-year flow through Moira River	5.49 m^3/s
20 percent of the 100-year flow through Moira River	10.98 m^3/s
30 percent of the 100-year flow through Moira River	16.47 m^3/s

It should be noted that, due to the lack of flow data as well as the relatively flat nature of the Young's Creek Area, particularly in the onsite portion of the creek, several inherent limitations of the model exist. These limitations are explained in more detail in the Floodplain Mapping Final Report (CG&S, November 1998). Flow velocities for the 100-year storm flow are shown in Table 3.1.

TABLE 3.1
FLOW VELOCITIES IN YOUNG'S CREEK WITH FLOW EQUAL TO 30 PERCENT OF THE 100-YEAR STORM FLOW THROUGH MOIRA RIVER

Cross-Section Number (m)	Channel Mean Flow Velocity (m/s)	Cross-Section Number (m)	Channel Mean Flow Velocity (m/s)
0	0.78	1505	1.7
42	0.52	1520	0.59
55	1.83	1590	2.23
83	1.62	1795	0.42
99	0.3	1920	0.97
135	0.23	1995	2
215	0.16	2055	0.84

TABLE 3.1
FLOW VELOCITIES IN YOUNG'S CREEK WITH FLOW EQUAL TO 30 PERCENT OF THE 100-YEAR STORM FLOW THROUGH MOIRA RIVER

Cross-Section Number (m)	Channel Mean Flow Velocity (m/s)	Cross-Section Number (m)	Channel Mean Flow Velocity (m/s)
565	0.27	2215	0.47
950	0.2	2435	0.19
1265	0.35	2600	1.33
1445	0.96	2620	0.53

The flood risk map, shown in Figure 3-2, identifies the 100-year flood boundary, which ranges between flood elevations of 188.0 and 188.5 metres above sea level (masl) for the Young's Creek Area south of the east tailings dam. The model predicts that the majority of the sediments within the Young's Creek Area will be submerged; therefore, there is an increased likelihood of the contaminated sediments within this area being re-suspended. Similarly a concern exists that impacted sediment contained behind a series of beaver dams present in the offsite portion of Young's Creek could be released into the Moira River should the dams be breached during a flood event such as a 100-year flood.

3.3 Natural Environment

An ecological inventory of the Deloro Mine Site property was initially conducted during the summer of 1997 (CG&S, 1999). The objectives of the inventory were to:

- Characterize fish, vegetation, and wildlife habitat on the site
- Assess the habitat characteristics that contribute to the various assemblages found
- Detect the presence of significant species or groups that could constrain remediation options

Documenting the presence or absence of certain organisms provided preliminary information on whether there are qualitative effects of the contaminated media at the site on the local ecological receptors.

Subsequently, the impact of Deloro Mine Site activities on natural features in Young's Creek was evaluated by Snider's Ecological Services (Snider, 2001). The objectives of this study were to investigate:

- The significance of the Deloro Wetland Complex and possible impact of mine site and remedial work on the wetland

- The significant species and significant habitat and possible impact of mine site and remedial work on these features

- Significant wildlife populations and possible impact of mine site and remedial work on these populations

In addition to the CH2M HILL and Snider studies, Golder Associates and Global Tox International subsequently completed a study entitled *Phase II Moira River Study Impacts of the Former Deloro Mine Site on the Moira River System* (Golder, 2001). The following questions were addressed in this study:

- Are metals entering the Moira River system?
- Is there a measurable biological response in aquatic invertebrates and fish?
- Are the metals in the system causing the biological response observed in invertebrates and fish?
- Do the metal concentrations present in water and sediment of the Moira River system pose a risk to human health?
- What amount of cleanup would be necessary at the Deloro Mine Site to meet Provincial Water Quality Objectives in the Moira River and to reduce sediment concentrations to below concentrations associated with biological effects?

The following paragraphs provide excerpts from the *Ecological Inventory Final Report* (CG&S, 1999) and a brief summary of the key findings of the Snider and Golder/Global Tox International studies as they relate to aquatic and terrestrial ecology. Readers of this report are directed to the above noted studies, which provide a comprehensive overview of the natural environment and ecology of the area.

3.3.1 Wetland Designation

Young's Creek was previously designated as two separate wetland complexes. The onsite portion of Young's Creek located on the former Deloro Mine Site is part of a much larger designation called the Deloro Wetland Complex. A wetland evaluation was initially conducted in 1990 using the former 1983 wetland evaluation system for the onsite portion of Young's Creek. The wetland was evaluated at 605 points, just over the minimum scoring criteria of 600 out of 1000 possible points needed for a Provincially Significant Wetland (PSW) designation. During the same time period, the offsite portion of Young's Creek located south of Highway 7 was also evaluated and designated as a PSW.

As both of the above noted PSW's are located at the southern extremity of the Canadian Shield, it should be noted that the Provincial Policy Statement indicates that "development and site alteration may be permitted in significant wetlands in the Canadian Shield." This is provided that it can be demonstrated that there will be no negative impacts on natural features, or ecological functions for which the area has been identified.

The MOE retained Snider's Ecological Services to re-evaluate the Deloro Wetland Complex in the summer of 2000. This evaluation was completed using the more rigorous 3rd edition of the wetland evaluation manual and included the wetland south of Highway 7. A principal objective of the Snider Study was to investigate the significance of the Deloro Wetland Complex and the possible impact of proposed remedial work on the wetland.

The basic conclusions of the Snider Study are summarized below. The reader is referred to the Snider Study for complete details:

- The wetland re-evaluation completed by Snider concluded that the Deloro Wetland Complex was evaluated as a Class 2 provincially significant wetland.
- The presence of contaminated sediment and associated mine activities did not significantly impact the wetland evaluation score as the most heavily impacted area of Young's Creek south of the Tailings Area comprises only 32 percent of the whole wetland.
- An impaired vegetation community consisting of horsetail and red top grass was identified along the west side of Young's Creek below the Tailings Area. It was indicated that removal of highly contaminated red sediment from this area would result in a more diversified vegetation community.
- No provincially significant species of amphibians, reptiles, birds, mammals, or plants were observed in the Deloro Wetland Complex or associated uplands.
- The study concluded that the wetland types encountered in the wetland evaluation in the Deloro Wetland Complex were not rare and distinct with the exception of a small isolated bog located upstream of the Tailings Area.
- The basic conclusions of the study were that removal of contaminated sediments would reduce levels of arsenic and other metals in aquatic species and would subsequently be considered an improvement to the social values component of the wetland.
- The study also concluded that remedial efforts will not impact any known significant species and that removal of contaminated sediments will likely result in a more diversified vegetation community and could improve the possibility of significant species occurring in the area.
- The study recommended that a simple wetland restoration plan be prepared once the remediation process for impacted sediments in Young's Creek is identified.

3.3.2 Aquatic Ecology

Based on the electrofishing assessment conducted by CH2M HILL during the ecological inventory, the two observation stations within Young's Creek identified six different types of warm/cool water fish species (34 fish in total). The variety of fish species caught during this inventory was sufficient to suggest that toxicity impacts, if any, are low enough to permit survival of a diversified fish community.

The benthic invertebrate communities were examined in the Golder/Global Tox International Study in several locations within the study area for differences in abundance, overall species composition, and the presence/absence of sensitive species. Analysis of the effect of Young's Creek sediments on the benthic invertebrate communities revealed that they reduced the abundance and species richness. Young's Creek sediments were toxic to freshwater shrimp (*Hyalella azteca*) and midge (*Chironomus riparius*). The concentrations of the metals of concern in fish fillets were determined to be below levels that would require restrictions of fish consumption. The Golder/Global Tox International Study also indicated

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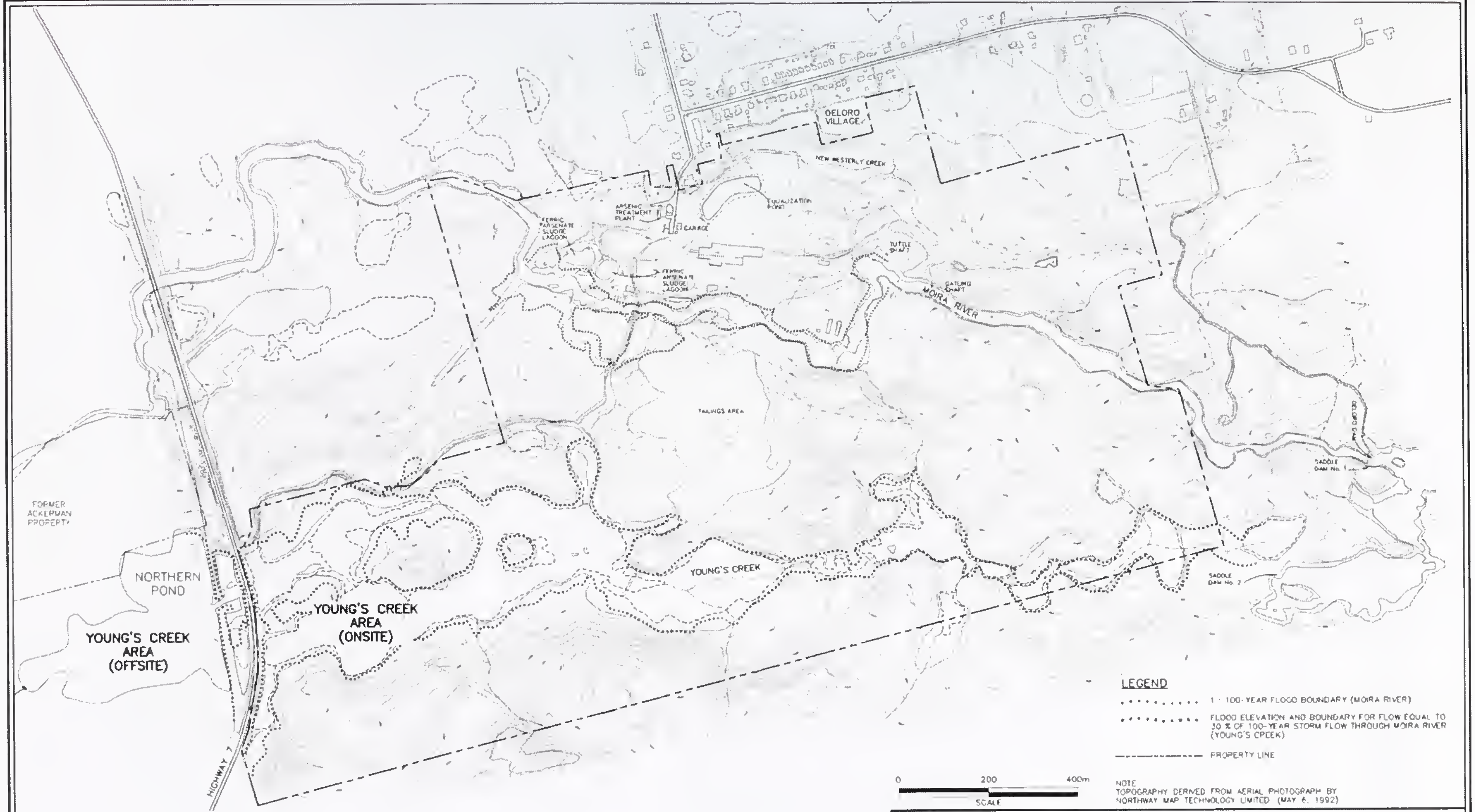
DELORO VILLAGE
NEW WESTERLY CREEK
EQUALIZATION POND
ARSENIC TREATMENT PLANT
GARAGE
FERRIC ARSENATE SLUDGE LAGOON
FERRIC ARSENATE SLUDGE LAGOON
TUTTLE SHAFT
GATLING SHAFT
MOIRA RIVER
TAILINGS AREA
DELORO DAM
SADDLE DAM No. 1
SADDLE DAM No. 2
YOUNG'S CREEK
YOUNG'S CREEK AREA (ONSITE)
YOUNG'S CREEK AREA (OFFSITE)
NORTHERN POND
FORMER ACKERMAN PROPERTY
HIGHWAY 7
LEGEND
1 : 100-YEAR FLOOD BOUNDARY (MOIRA RIVER)
FLOOD ELEVATION AND BOUNDARY FOR FLOW EQUAL TO 30 % OF 100-YEAR STORM FLOW THROUGH MOIRA RIVER (YOUNG'S CREEK)
PROPERTY LINE
0
200
400m
SCALE
NOTE
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPH BY NORTHWAY MAP TECHNOLOGY LIMITED (MAY 6, 1992)

CH2MHILL

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-2
YOUNG'S CREEK FLOODPLAIN

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that the final cleanup plan for the Deloro Mine Site does not need to include consideration of the effects in the downstream aquatic environment because benthic invertebrates and fish populations did not exhibit adverse effects from the presence of metals in the Moira River system.

The Snider Study indicated that no provincially significant species were observed in the Deloro Wetland Complex or associated uplands.

3.3.3 Vegetation and Wildlife Ecology

The Young's Creek Area consists primarily of wetland with bedrock outcrops and scarps to the east and west in the onsite portion of the creek. The east branch of Young's Creek and parts of the creek to the north and east of the Tailings Area are dominated by a dense mixture of grasses, rushes and sedges. Woody species tend to be confined to the perimeter of the marsh with denser shrubbery in the northernmost parts of the creek. The vegetation of the west arm of Young's Creek and channels leading from the Tailings Area are visibly and qualitatively different from the vegetation community that characterizes the east and north parts of the creek. The west arm sustains atypically sparse vegetation, which is dominated by an unusual community of field horsetails and red-top grass. In the offsite portion of the Young's Creek Area, the vegetation surrounding the ponds consists primarily of trees and shrubs. Some of the more common trees encountered include white birch, black ash, red maple, sugar maple, and balsam poplar. As noted in the Snider Study, 19 different species of trees and 25 different varieties of shrubs were identified in the overall Deloro Wetland Complex. Other vegetation encountered included ferns, mosses and horsetails, graminoids, and a wide variety of herbacious plants. The Snider Study concluded that the wetland types encountered in the evaluation of the Deloro Wetland Complex were not rare and distinct with the exception of a small isolated bog located upstream of the Tailings Area.

Wetlands in the west arm of Young's Creek in the onsite area supported a lower diversity of marsh-nesting species (such as red-winged blackbird and swamp sparrow) than other marshes, probably because the vegetation is extremely sparse in this location, with very little concealment cover or nesting habitat for most birds. All birds noted from the west arm of Young's Creek were located in the denser vegetation at the edge of the wetland. No provincially or locally rare species were found.

The species assemblage of amphibians (seven species) was also typical of swamps and marshes in the area, with no significant species found. The west arm of Young's Creek supported a low abundance of breeding frogs during the spring breeding surveys, again likely due to the scarcity of standing water and the lack of concealing vegetation. Frogs were found to be relatively common in this area later in the summer.

Mammals noted at the site included thirteen species that are widespread in forested areas of Ontario. A total of eleven bird species were identified in the Deloro Wetland Complex in the Snider Study. Deer were identified as the dominant herbivore in the area and beavers were identified as playing a dominant role in the ecology of the area. Beavers have placed dams throughout the Young's Creek watershed, both onsite and offsite, modifying water levels and creating extensive marshes. Most of the Deloro Wetland Complex was formed as a result of the activities of beavers in the area. Beaver dams impound sediments that accumulate to substantial depths and have the potential to be released suddenly in storm events or more slowly when abandoned dams deteriorate.

3.3.4 Social Conditions

The Young's Creek Area is part of the larger Moira River watershed; therefore, any impacts attributed to the Young's Creek Area could consequently impact the social conditions associated with the Moira River. The Young's Creek Area is located in the old Township of Marmora and Lake.[5] The creek originates in an area of low topography just south and east of the Deloro Dam and Reservoir and flows in a southerly direction before discharging into the Moira River approximately two kilometres south of Highway 7. The Moira River continues easterly into Moira Lake and, from there, flows southerly to the Bay of Quinte.

The land use within the Young's Creek catchment area and along the Moira River within the old Township of Marmora and Lake is primarily zoned as environmentally protected areas, with the surrounding land uses primarily zoned as rural. Development along the Moira River and Young's Creek, from Deloro to Moira Lake, is generally sparse. The Moira River Conservation Authority indicated that 11 houses and three farms are adjacent to this section of the Moira River. Nine of these houses are located at the mouth of the river at Moira Lake.

Use of the Moira River, Young's Creek and Moira Lake within the old Township is primarily recreational, consisting of fishing and boating. Potable water within the Township is obtained primarily via private wells. Discussions with the Moira Lake Property Owners' Association also indicated that most landowners in the area are aware of the concerns associated with water quality, and consequently there are no potable uses of river or lake water. There appears to be very little agricultural land near the Moira River, Young's Creek or Moira Lake. Consequently, use of the river or lake for agricultural purposes is also unlikely. Readers are directed to the *Survey of Moira River Water Use - Update, Final Technical Memorandum* (CG&S, October 1998c) for further details.

3.4 Contaminants in Young's Creek

CH2M HILL conducted an investigation of the sediment quality in the onsite section of the Young's Creek floodplain in the vicinity of the Deloro Mine Site north of Highway 7 in 1997 and 1998. The onsite investigation findings revealed that sediments impacted with primary indicator metals arsenic, copper, cobalt, nickel, and uranium, are present in the Young's Creek floodplain north of Highway 7. Details of the findings of the onsite investigation are presented in CH2M HILL's Technical Memorandum entitled *Task #623C – Delineation of Young's Creek Sediments, Deloro Mine Site* (CH2M HILL, May 2001).

Subsequently, Golder Associates and Global Tox International completed a study entitled *Phase II Moira River Study Impacts of the Former Deloro Mine Site on the Moira River System* (Golder, 2001). The study recommended that further characterization of sediment and water quality in Young's Creek south of Highway 7 should be conducted. The MOE retained CH2M HILL to conduct an investigation of the offsite sediments in Young's Creek in the fall of 2000.

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[5] The recent amalgamation has changed the jurisdiction this township falls under.

The offsite investigation was conducted in two stages with the first stage being conducted in November 2000 and the second stage being completed during January and February 2001. The investigation consisted of the identification and assessment of all beaver dams in Young's Creek south of Highway 7 and the evaluation of the extent and quality of sediments throughout the offsite portion of Young's Creek to the confluence of Young's Creek and the Moira River (approximately 1.7 km). The findings of the offsite investigation are presented in CH2M HILL's report entitled *Delineation of Offsite Sediments and Clay Deposits in Young's Creek and Assessment of Beaver Dams* (CH2M HILL, March 2003).

A general summary of the principal findings from the onsite and offsite investigations is provided below. For further details, the reader is referred to the above noted reports.

3.4.1 Inorganic Contaminants

Onsite Results

Based on the results of the several geochemical investigations within the Young's Creek Area, arsenic, cobalt, copper, nickel, uranium, lead, and silver have been found at varying concentrations throughout the Young's Creek Area south of the east tailings dam. Although contamination appears to be greatest in the upper red mud and organic layers of sediments, concentrations that exceed the MOE Severe Effect Level (SEL) and the Open Water Disposal Guideline (OWDG) for cobalt exist up to at least 1.5 mbgs as far south as the southern tip of the large island outcrop. The following paragraphs briefly describe the extent to which each of the above seven indicator inorganic contaminants is present within the Young's Creek Area. Concentrations of seven metals in addition to those listed above also exceeded either their applicable LEL or the MOE Table A residential/parkland criteria for soil, where no sediment quality criteria exist. However, the metals mentioned first above were identified and retained as indicator metals in Young's Creek due to the frequency and magnitude of elevated concentrations across the site, and as field observations identified sediment, and not soil, conditions onsite at the time of the investigations. The additional metals will be evaluated, as appropriate, in the Site Specific Risk Assessment. The distribution of concentrations for the principal constituents of interest found in the 1997 and 1998 sediment investigations is shown in Figure 3-3A. For a more detailed summary of the distribution for the principal contaminants of concern the reader is referred to the CH2M HILL report entitled: *Deloro Mine Rehabilitation Project Onsite Data Summary, Final Report* (CH2M HILL, February 2002), which presents contaminant concentration contour plots.

Arsenic concentrations range from 7.1 µg/g to as high as 110,000 µg/g in the upper layers of sediment. The highest concentrations of arsenic are found in the upper northwest portions of Young's Creek adjacent to the Tailings Area seepage area. Generally, the arsenic concentrations gradually decrease to the south to Highway 7 as well as from the middle of the Young's Creek Area outward towards the high water marks of the east and west banks of the floodplain. Arsenic concentrations as high as 1,200 µg/g have been detected at depths of 1.0 m in the northern parts of the Young's Creek Area. The distribution of arsenic concentrations found in the 1997 and 1998 sediment investigations is shown in Figure 3-3A.

The distribution patterns for copper concentrations in the upper sediment layers are similar to those of arsenic, with the highest concentrations found in the northwest corner of Young's Creek adjacent to the tailings seepage area; the concentrations decrease to the south and along the banks of the floodplain. The concentrations of copper in upper sediment range from less than the laboratory reporting limit to as high as 16,000 µg/g (SD 4009). Copper concentrations as high as 140 µg/g have been detected at depths up to 1.0 m within the Young's Creek Area. The distribution of copper concentrations is also shown in Figure 3-3A.

The distribution patterns for nickel concentrations in the upper sediment layers are similar to both arsenic and copper. The concentrations range from 11 µg/g to as high as 6,100 µg/g with the majority of high concentrations detected in the northwest corner. Nickel concentrations as high as 65 µg/g have been detected at depths up to 1.0 m within the Young's Creek Area. The distribution of nickel concentrations is shown in Figure 3-3A.

Lead and silver showed similar distribution patterns as arsenic, copper, and nickel, with the greatest concentrations detected in the northwest corner of Young's Creek. Concentrations range from below the laboratory detection limit to 520 µg/g for lead and from below the laboratory detection limit to 16 µg/g for silver. Lead concentrations as high as 16 µg/g have been detected at depths up to 1.0 m.

Cobalt concentrations, although similar to the above five contaminants in distribution, were detected at elevated concentrations deeper than the other five contaminants in a few locations. The concentrations in the upper sediment layers ranged from less than the laboratory reporting limit to as high as 5,800 µg/g, which significantly exceed the OWDG LEL of 50 µg/g. These concentrations also exceed the screening level concentration of 296 µg/g developed by Golder Associates / Global Tox International during the completion of the Phase II Moira River Study (MRS, Golder, 2001). Cobalt concentrations as high as 100 µg/g have been detected at depths up to 1.0 m and a concentration of 110 µg/g was detected in one location at a depth of 1.5 m, which is below the MRS screening level concentration, but greater than the OWDG LEL for cobalt. The distribution of cobalt concentrations is shown in Figure 3-3A. (Summaries of the concentration for cobalt, copper, nickel and arsenic for each of the discrete sampling locations is provided in the Technical Memorandum entitled *Delineation of Young's Creek Sediments, Deloro Mine Site* [CH2M HILL, May, 2001] and in the *Onsite Data Summary* Report referenced previously).

In March 1999, CH2M HILL conducted a trial excavation of frozen Young's Creek sediments (CH2M HILL, June 2001b). The objectives of the investigation were to determine the feasibility of excavating frozen contaminated material from Young's Creek, as well as to further delineate the impacted materials at depths below 1.5 mbgs. The investigation found that the ice and frost cover offers a stable work platform, and that excavation activities in Young's Creek should be conducted during the winter months. It also found that the lower sediments in Young's Creek have concentrations consistent with background samples collected by the MOE in 1986. These concentrations marginally exceed the respective LELs for nickel and copper in all sampling locations. A cobalt concentration of 72 µg/g was detected immediately downstream of the east tailings dam in the sandy layer at bedrock (4.9 mbgs), which is below the MRS screening level concentration of 296 µg/g for cobalt but above the OWDG LEL of 50 µg/g. However, cobalt concentrations in the silty clay layer at 4.2 mbgs at the same location were well below the MRS screening level concentration and the OWDG LEL of 50 µg/g. The sand layer is a preferential pathway for the migration of contaminants. Based on this limited data, this potentially indicates that elevated cobalt below 1.5 m is an exception and not indicative of widespread contamination.

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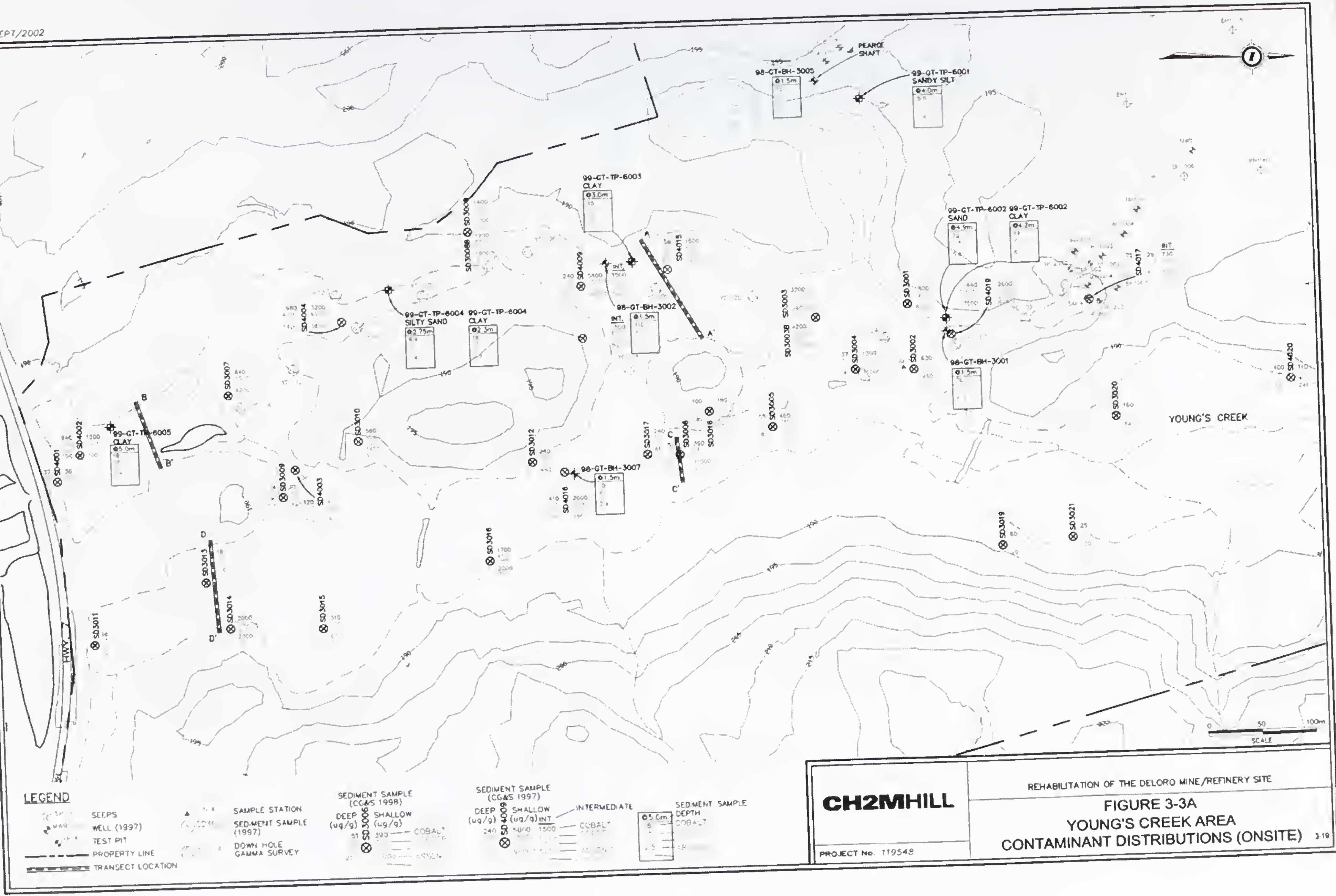

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-3A
YOUNG'S CREEK AREA
CONTAMINANT DISTRIBUTIONS (ONSITE)

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3.4.2 Radioactivity Levels

Onsite Results

The gamma activity survey performed by SCIMUS Inc. (CG&S, June 1999) indicated a large portion of the western half of Young's Creek between the east tailings dam and immediately south of the large island outcrop was contaminated with radioactive tailings. As summarized previously in Section 2.3.3, radiation fields up to 3 μSv/h were measured at surface and radium contents up to 100 Bq/g were measured in samples taken from a depth of 10 cm to 40 cm bgs. The denser clayey material beneath the sediments limited the radioactive fields. Consequently, the radioactivity is considered to be associated only with the contaminated sediments.

Uranium concentrations in this area ranged from 106 to 6290 μg/g according to the onsite Delineation of Young's Creek Sediments report (CH2M HILL, 2001) and were mainly contained to the upper sediment layers. A discontinuous layer of arsenic-rich red mud sediments and radioactive tailings, containing high gamma radiation and high uranium concentrations (up to 6,290 μg/g), was also identified beneath the organic material at depths ranging between 0 and 0.7 mbgs, as presented in the report entitled *Extent and Character of Radioactive Materials Final Report* (CG&S, 1999). This red mud was most prevalent in the area immediately to the east of the east tailings dam and within the northern portion of the Young's Creek floodplain. This low-level radioactive field that exists in Young's Creek may pose a human health or ecological hazard both as it exists in place as well as via suspended particulate from dried radioactive sediment.

Offsite Results

Based on these findings, the arsenic-rich red mud/radioactive tailings were not expected to be encountered downstream in the offsite portion of Young's Creek during the offsite investigation. As discussed below, uranium concentrations were not detected at elevated levels for any of the samples collected in the offsite portion of Young's Creek and screening of the samples using a Victoreen 190 meter did not reveal any radioactive contamination above background levels.

The sediment sampling conducted in the offsite section of Young's Creek was completed in two stages with the first being conducted in November 2000 and the second in January and February of 2001. The Fall 2000 sampling program involved the collection of seventeen (17) sediment samples including duplicates from eleven (11) locations near the eastern and western sides of the Northern and Southern Ponds and near the eastern edge of the Central Pond and in the creek channel at the outlet of the Southern Pond. All samples from the Fall 2000 sampling program were collected from depths ranging between 0 to 0.4 m below ground surface.

The Winter sampling program completed in January and February of 2001 involved the collection of one hundred and twenty five (125) sediment samples including duplicates from forty-four (44) locations. All samples from the Winter 2001 sampling program were collected from depths ranging between 0 to 3.6 m below pond bottom. The approximate location of the sampling points for both the Fall 2000 and the Winter 2001 sampling programs are shown on Figure 3-3B.

The results of the Fall 2000 and the Winter 2001 sediment sampling events were compared to the MOE's provincial sediment quality lowest effect level (LEL), severe effect level (SEL) and OWDG criteria (MOE, 1993). All samples were analyzed for the presence of arsenic, nickel, copper, cobalt, uranium, lead, and silver. The sampling results for cobalt and silver were compared to the screening level concentrations developed by Golder Associates/Global Tox International during the Phase II Moira River Study (MRS).

The concentrations of the indicator metals (arsenic, copper, cobalt, nickel, and uranium) at each sampling location for the Fall 2000 and Winter 2001 sediment sampling events conducted in the offsite section of Young's Creek are shown in Figure 3-3B.

The following summarizes the results of the sediment sampling investigation conducted in the offsite portion of Young's Creek in the vicinity of the Deloro Mine Site.

Fall 2000 Sampling Summary

- The results of the Fall 2000 sediment sampling revealed that elevated concentrations of arsenic, copper and nickel are present in nearly all samples at concentrations exceeding either the severe effect level (SEL) or lowest effect level (LEL) sediment quality criteria. Cobalt concentrations were elevated above its LEL (from the OWDG) in six samples, but were below the MRS screening level concentration at all but two sampling locations.
- The maximum uranium concentration detected in samples from the Fall 2000 sampling program was 7.03 µg/g (SD-2007), well below 129 µg/g, which is the upper end of the range considered to be representative of typical uranium background sediment concentrations in the Canadian Shield Area.

Winter 2001 Sampling Summary

- Elevated concentrations of arsenic were detected in over 80 percent of all samples collected during the Winter 2001 sampling program. Arsenic was detected in the majority of samples at concentrations exceeding either the lowest effect level (LEL) or the severe effect level (SEL) criteria. Arsenic concentrations were found to be highest in the upper organic sediment unit, where concentrations ranged between 7.9 µg/g (SD-2042) and 1460 µg/g (SD-2039). Conversely, concentrations were found to range from 1.8 µg/g (SD-2025) and 666 µg/g (SD-2039) in the upper silty clay unit.
- Elevated concentrations of nickel were present in all three ponds above either the SEL or the LEL criteria for this parameter in a pattern similar to that observed for arsenic. Over 89 percent of all samples collected during the Winter 2001 sampling program exceeded the LEL criteria, with 28 percent exceeding the SEL criteria. Nickel concentrations were also found to be highest in the upper organic sediment unit, where concentrations ranged between 11 µg/g (SD-2034) and 1570 µg/g (SD-2039). Contaminant concentrations in the upper silty clay unit below the organic sediment unit were found to range from 10 µg/g (SD-2031) and 904 µg /g (SD-2039).
- Copper concentrations were also detected at elevated levels in all three ponds above either the SEL criteria or the LEL criteria in a pattern similar to that observed for arsenic and nickel. Over 97 percent of all samples collected during the Winter 2001 sampling

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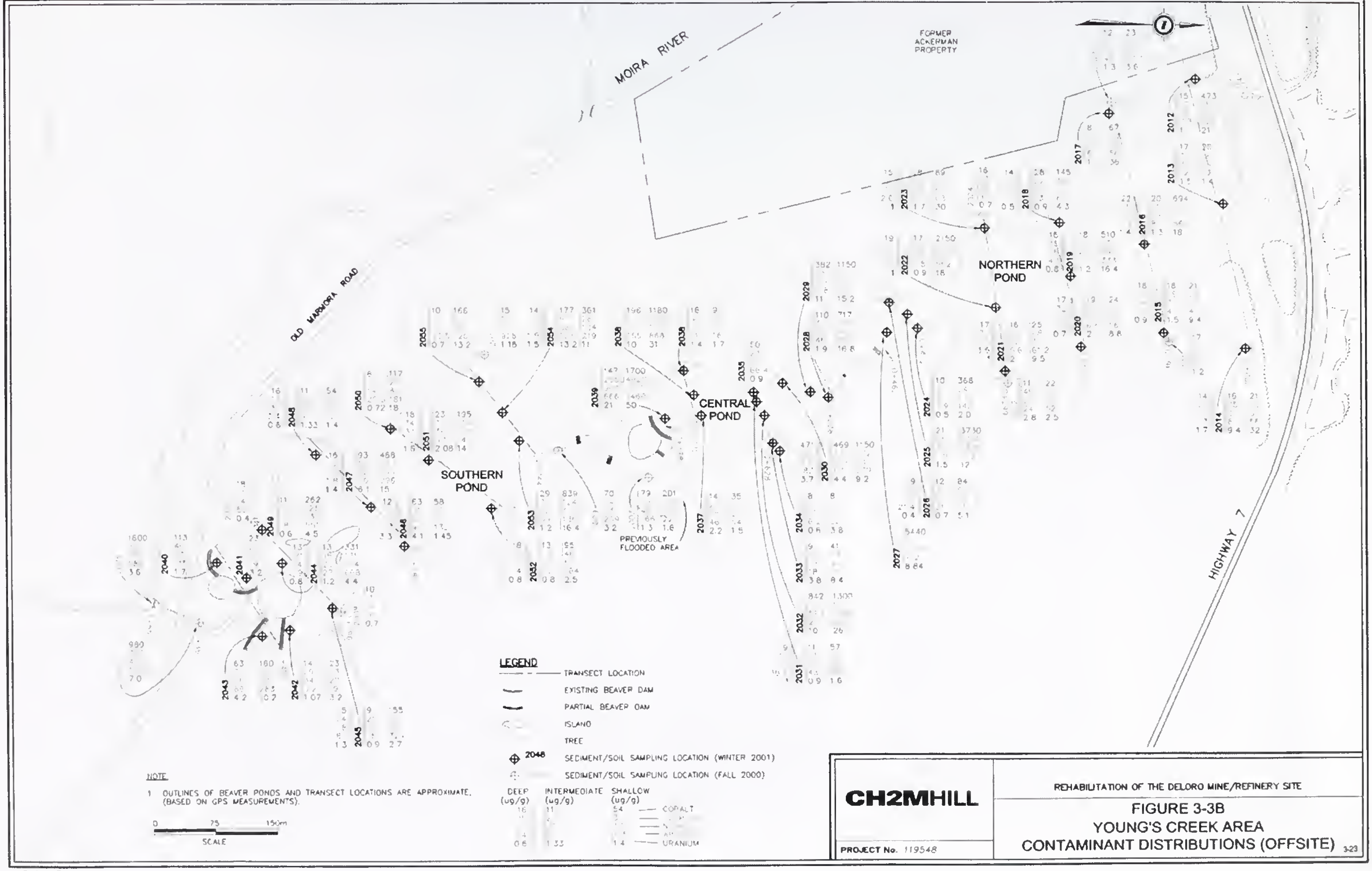

NOTE

1 OUTLINES OF BEAVER PONDS AND TRANSECT LOCATIONS ARE APPROXIMATE. (BASED ON GPS MEASUREMENTS).

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-3B
YOUNG'S CREEK AREA
CONTAMINANT DISTRIBUTIONS (OFFSITE)

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program exceeded the LEL criteria, with 26 percent exceeding the SEL criteria. Copper concentrations were also found to be highest in the upper organic sediment unit, where concentrations ranged between 7 µg/g (SD-2034) and 5190 µg/g (SD-2032). Contaminant concentrations in the upper silty clay unit below the organic sediment unit were found to range from 8 µg/g (SD-2034) and 2550 µg/g (SD-2039).

- Cobalt concentrations were compared to the LEL provided by the OWDG as well as the screening level concentration (SLC) developed by Golder Associates/Global Tox International during the Phase II Moira River Study (MRS). Elevated concentrations of cobalt were detected to be present in all three ponds in the upper organic sediment unit above both the LEL and the MRS SLC. Over 40 percent of all samples collected during the Winter 2001 sampling program exceeded the OWDG LEL of 50 µg/g and 22 percent exceeded the MRS SLC of 296 µg/g for cobalt. Concentrations were found to be highest in the upper organic sediment unit, where concentrations ranged between 8 µg/g (SD-2034) and 5680 µg/g (SD-2027). Contaminant concentrations in the upper silty clay unit below the organic sediment unit were found to range from 8 µg/g (SD-2017) to 1470 µg/g (SD-2039).
- Uranium concentrations were not detected at elevated levels for any of the samples collected during the Winter 2001 sediment sampling program. Uranium concentrations in the upper organic sediment unit were found to range between 0.43 µg/g (SD-2034) and 49.7 µg/g (SD-2039), well below 129 µg/g, which is the upper end of the range considered to be representative of typical background sediment concentrations in the Canadian Shield Area (CG&S, June 1999). Uranium concentrations in the upper silty clay unit below the organic sediment unit were found to range from 0.54 µg/g (SD-2024) and 21 µg/g (SD-2039).
- During this investigation 118 sediment and soil samples were screened with a Victoreen 190 meter equipped with pancake probe to check for the presence of alpha, beta and gamma radiation. This initial screening did not reveal any radioactive contamination above background levels.
- Lead concentrations were not detected in all three ponds above the SEL criterion of 250 µg/g. Lead concentrations were also below the LEL criterion of 31 µg/g at the majority of sampling locations with the exception of 11 locations. Lead concentrations were also found to be highest in the upper organic sediment unit where concentrations ranged between 5 µg/g (SD-2041) and 84 µg/g (SD-2053).
- The sampling results for silver were also compared to the LEL provided by the OWDG as well as the screening level concentration (SLC) developed by Golder Associates/ Global Tox International during the Phase II Moira River Study (MRS). Twelve percent of the sampling results for silver from the Winter 2001 sampling program exceeded the LEL of 0.5 µg/g, while all the analytical results were below the MRS SLC of 5.1 µg/g. Silver concentrations were also found to be highest in the upper organic sediment unit where concentrations ranged between 0.1 µg/g (SD-2041) and 2.6 µg/g (SD-2032).
- Vertical contaminant distribution plots created for samples collected along the approximate centreline of all three ponds revealed that arsenic concentrations in the organic sediments significantly exceed the MOE SEL criteria of 33 µg/g in most cases.

The arsenic results for the upper silty clay unit also revealed that a significant number of samples also exceeded the SEL criterion with some exceptions. For the lower silty clay unit, all samples were below the SEL criterion and the majority were also below the LEL criterion.

- The vertical contaminant profiles for nickel, copper and cobalt show very similar findings as those observed for arsenic, except that the concentrations in the lower silty clay unit were between the MOE LEL and SEL sediment quality criterion. Cobalt concentrations fell between the OWDG LEL and the MRS SLC.

Comparison of Offsite Lower Clay Samples to Typical Background Concentrations

A comparison of the concentration ranges detected in the lower silty clay unit for the four principal constituents of interest with typical Ontario background values and local background soil data collected in the vicinity of the Deloro Mine Site is presented in Table 3.2. It is recognized that by comparing onsite background soil data and offsite subsurface sediments, some consideration must be given to the variations in these media and there respective environments, but in general, comparing the two for general benchmark purposes is considered appropriate.

Comparison of the geochemical concentrations in the lower silty clay unit with typical background soil concentrations in Ontario (MOE's Table F in the *Guideline for Use at Contaminated Sites in Ontario)* show that these concentrations, in most cases, are often representative of background levels. However, there are also anomalously high concentrations in this unit for arsenic, nickel, copper and cobalt at sampling location SD-2030, located beneath the Central Pond. Three other sampling locations beneath the Northern (SD-2015 and SD-2026) and Central Ponds (SD-2031) had arsenic concentrations in the lower silty clay unit that slightly exceeded the typical background soil concentrations for arsenic in Ontario.

The sediment sampling results were also compared to local background conditions in the general vicinity of the Deloro Mine Site. A comparison of the subject concentrations in the lower silty clay unit with local background information collected north and south of Deloro reveals that in the majority of cases concentrations for the principal constituents of interest are generally similar to local background conditions for arsenic, copper, nickel, and cobalt, as noted in Table 3.2. This is not considered overly significant as the local background data presented in Table 3.2 are based on a limited data set and are lower than typical Ontario background concentrations.

The maximum concentration of arsenic detected in the lower silty clay unit in the offsite portion of Young's Creek was 81.8 µg/g, with an average concentration of 9.9 µg/g, which is below typical Ontario background concentrations. A review of local ambient background soil data for the Deloro Mine Site itself indicates that elevated ambient background levels of the principal constituents of interest exist even in remote areas of the Deloro Mine Site, as a result of years of fugitive airborne emissions. For example, arsenic is typically found at a background level of approximately 100 µg/g in remote areas of the Deloro Mine Site (shown in Table 3.2). Further details of the distribution pattern for the principal contaminants of concern are presented in the CH2M HILL report entitled: *Deloro Mine Rehabilitation Project Onsite Data Summary – Final Report* (February 2002), which presents

Table 3.2
Comparison of Concentrations in Lower Silty Clay -vs- Ontario, Local, and Deloro Mine Site Background Concentrations

Contaminant	Concentration in Lower Clay/Silt (Centre line of ponds) µg/g	Concentration in Lower Clay/Silt (Eastern edge of ponds) µg/g	Concentration in Lower Clay/Silt (Western edge of ponds) µg/g	Ontario Background Concentrations [1] µg/g	Local Background Concentrations [2,3] µg/g	Deloro Mine Site Background Concentrations [4] µg/g	PSQG Background Concentrations [5] µg/g
As	1.5 to 8.8	2.3 to 18.9	2.6 to 81.8	14 to 17	3 to 8	25 to 100	4.2
Ni	8 to 33	23 to 36	5 to 131	43	14 to 15	5 to 50	31
Cu	24 to 35	26 to 45	17 to 68	56 to 85	10 to 15	5 to 50	25
Co	5 to 22	12 to 18	9 to 471	19 to 21	7 to 11	10 to 50	no value

Notes:

[1] MOE (1997), Guidelines for Use at Contaminated Sites in Ontario. Revised February 1997.
Values refer to soil. Low end of range applies to Agricultural Land Use, high end of range applies to All Other Land Uses. For nickel both values are the same.

[2] Concentration range derived by CH2M Gore & Storrie Limited and presented in "Results of Chemical Analysis to Determine Background Soil Quality at the Deloro Site" Memorandum, January 27, 1998.

[3] Upper end of concentration Range from "Investigation of Soil Contamination and Fill Materials, Former Ackerman Property. Golder Associates, May 1995" and lower end of concentration range from "Marmora Township Soil Analysis. MOEE, May 1994."

[4] Approximate soil concentration ranges for remote areas of the mine site, interpreted from contour figures presented in "Onsite Data Summary - Final Report, CH2M Hill, February 2002." Appendix A - Surficial Soil.

[5] MOE (1993), Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.
Table 4: Background Levels for the Metals. Values are based on analyses of Great Lakes pre-colonial sediment horizon.

contaminant concentration contour plots. As there were only a few locations in the lower silty clay unit where concentrations of the principal constituents of concern exceeded typical Ontario background levels and, as concentrations were similar to or less than local onsite background soil concentrations, these values are not considered significant.

The MOE *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario* (PSQG) background concentrations for sediment were also compared to the geochemical concentrations in the lower silty clay unit. The PSQG background concentration for arsenic (4.2 µg/g) is lower than the LEL of 6 µg/g. The PSQG background nickel concentration in sediment is approximately twice its LEL, while the PSGQ background concentration for copper is marginally above its LEL. (A background concentration for cobalt in sediment was not provided.) These PSQG concentrations are nonetheless within the range of the other background concentrations that have been applied in comparison above.

In addition to comparing the sediment sampling results from the lower silty clay unit with typical Ontario background levels for soil and with local offsite and onsite background soil concentrations, the sampling data was also compared to offsite sediment sampling results from the Moira River, as presented in the Phase II Moira River Study (MRS) (Golder, 2001). This data was considered important in helping to assess the overall significance of the sediment sampling results for the lower silty clay unit in comparison with sediment quality downstream in the Moira River.

In most cases, concentrations for the constituents of interest in the lower silty clay in the offsite portion of Young's Creek are equal to or better than the sediment quality downstream from the Deloro site in the Moira River, and Moira and Stoco Lakes (Golder, 2001). The concentrations of arsenic, cobalt and nickel remain greater than 100 µg/g in sediment grab samples collected downstream of the offsite portion of Young's Creek in the Moira River until Stoco Lake, while copper was detected at concentrations between 25 µg/g and 110 µg/g in those samples. The MRS indicated that the final cleanup plan for the Deloro Mine Site does not need to include consideration of the effects in the downstream aquatic environment because benthic invertebrates and fish populations did not exhibit adverse effects from the presence of metals in the Moira River System.

As the concentrations of the constituents of interest in the lower silty clay units in the offsite portion of Young's Creek are generally consistent or better than sediment quality downstream, remedial efforts associated with this material is unlikely to yield significant benefits that would justify remedial costs.

Comparison Between Onsite and Offsite Sampling Results

A comparison between the onsite and offsite sediment sampling results for Young's Creek is presented in Table 3.3. The maximum, minimum, average, and median sampling results for the principal constituents of concern analyzed during both investigations were calculated. The results are presented for both the onsite and offsite data for the organic sediment unit and for the silty clay units located beneath it.

Table 3.3
Concentrations in Sediment, Upper and Lower Clay - Comparison to Onsite vs Offsite in Young's Creek

			Contaminant						
			Arsenic	Nickel	Copper	Cobalt	Silver	Uranium	Lead
Concentrations in Sediments	Concentration Onsite (µg/g)	Maximum (A)	110000 [SD 3003B] (90000 [SD 4009])	6100 [SD 4009]	16000 [SD 4009]	5800 [SD 4009]	10 [SD 4009]	420 [SD 3001]	520 [SD 4009]
		Minimum	3	11	<1	<5	<1	<5	14
		Average	16503 (13581)	940 (860)	3052 (2772)	1179 (1084)	1.4 (1.5)	66 (61)	137 (148)
		Median	1400 (1300)	350 (305)	480 (470)	630 (595)	<1	32 (27.5)	27 (29)
	Concentration Offsite (µg/g)	Maximum (B)	1460 [SD 2039*] (1380 [SD 2039])	1570 [SD 2039*] (1470 [SD 2039])	5190 [SD 2032]	5680 [SD 2027*] (5440 [SD 2027])	2.6 [SD 2032]	49.7 [SD 2039*] (48.6 [SD 2039])	84 [SD 2053]
		Minimum	7.9	11	7	8	0.1	0.43	5
		Average	325 (302)	316 (283)	751 (682)	647 (607)	0.57 (0.54)	12.28 (11.9)	24.3 (23.7)
		Median	162 (142)	90 (79)	125 (117)	163 (185)	0.4	9.43 (9.28)	19.5 (18.5)
	Onsite / Offsite ratio	A/B	75 (65)	3.9	3.1	1.0	3.8	8.5	6.2
Concentrations in Upper and Lower Clay	Clay Concentration Onsite (µg/g)	Maximum (A)	7500 [SD 4019-2]	1300 [SD 4009-2]	10000 [SD 4019-2]	1500 [SD 4009-2]	16 [SD 4019-2]	50 [SD 3018]	69 [SD 4019-2]
		Minimum	<1	20	15	14	<1	11	5
		Average	1800	261	1652	368	3.73	29	28
		Median	245	63	108	110	0.5	28	24
	Upper Clay Concentration Offsite (µg/g)	Maximum (B)	666 [SD 2039]	904 [SD 2039]	2550 [SD 2039]	1470 [SD 2039]	1 [SD 2039]	21 [SD 2039]	27 [SD 2039]
		Minimum	1.8	10	8	8	0.05	0.54	2.5
		Average	49 (52)	65 (70)	110 (122)	97 (106)	0.24 (0.27)	3.16 (3.3)	8.04 (8.94)
		Median	11.4 (13)	275 (26)	31	17	0.15	1.41 (1.43)	8
	Onsite / Offsite ratio	A/B	11	1.4	3.9	1.0	16	2.4	2.5
	Lower Clay Concentration Offsite (µg/g)	Maximum	81.8 [SD 2030]	131 [SD 2030]	68 [SD 2030]	471 [SD 2030]	0.05 [multiple]	3.72 [SD 2030]	9 [SD 2021]
		Minimum	1.5	5	17	5	0.05	0.42	2.5
		Average	9.9 (11.1)	30.84 (30.85)	30.56 (30.81)	32.96 (36.33)	0.1 (0.10)	1.2 (1.28)	7.3 (7.25)
		Median	3.5 (4)	29 (29)	31 (32)	16 (15)	0.1 (0.1)	0.97 (1.03)	8 (8)
	Combined Clay Concentration Offsite (µg/g)	Maximum	666 [SD 2039]	904 [SD 2039]	2550 [SD 2039]	1470 [SD 2039]	1 [SD 2039]	21 [SD 2039]	27 [SD 2039]
		Minimum	1.5	5	8	5	0.05	0.42	2.5
		Average	36 (39)	53 (57)	83 (92)	75 (83)	0.1	2.5 (2.6)	8.3
		Median	8.1 (8.9)	29	31	16	0.1	1.2 (1.3)	8.0

Notes:
(234) = numbers in brackets indicate values calculated without duplicates
[SD 3001] = indicates sample location
[multiple] = indicates more than one sample location
* = duplicate sample location
The analytical data used to calculate the statistics in this table does not include the offsite sediment sample results from the Fall 2000 round of sampling as these samples were collected from the edges of the ponds and are not considered representative of pond bottom conditions.
This table does not include the results of the seven samples collected and analyzed for uranium as reported the Extent and Character of Radioactive Materials Final Report (CG&S, 1999).

The results presented in Table 3.3 indicate that, for the organic sediment unit, the maximum arsenic concentration detected in sediments onsite was 110,000 µg/g, while offsite arsenic concentrations were detected in sediments at 1460 µg/g. The maximum offsite concentration for arsenic in the organic sediment unit was approximately 75 times lower than the maximum concentration of arsenic in the onsite Young's Creek Area. A comparison of the maximum arsenic concentrations between offsite and onsite areas for the upper silty clay unit revealed that arsenic concentrations are approximately 11 times lower than the maximum onsite arsenic concentration for this unit. A review of the sampling results for the lower silty clay unit in the offsite area of Young's Creek for arsenic revealed a maximum concentration of 81.8 µg/g with an average concentration of 9.9 µg/g, which is below typical Ontario background concentrations.

A comparison of the copper, nickel, and silver concentrations within sediments in the onsite Young's Creek Area versus the offsite area reveals that these maximum offsite concentrations were between three and four times lower than the maximum concentrations of copper, nickel and silver within sediments in the onsite Young's Creek Area. While the maximum offsite concentration of cobalt identified in sediments was essentially the same as that found onsite, the median and average cobalt concentrations were lower offsite.

A comparison of the cobalt and nickel concentrations in the upper silty clay unit revealed that the maximum offsite concentrations were essentially the same for cobalt and 1.4 times lower than the maximum concentrations for nickel within the same unit in the onsite Young's Creek Area. However, the average concentrations of cobalt and nickel in the offsite silty clay unit are approximately four times less than the same average for the onsite Young's Creek Area. The maximum offsite concentration of copper in the upper silty clay unit was approximately four times lower offsite than the maximum concentration of copper in the same unit in the onsite Young's Creek Area and sixteen times lower for silver.

The maximum onsite concentrations in sediment for uranium and lead were 8.5 and 6.2 times greater, respectively, than the maximum offsite concentrations in sediment. Comparing upper silty clay results for uranium and lead revealed that the offsite maximum concentrations were approximately two and a half times lower than maximum concentrations in this unit onsite.

Overall, the results indicate that although still elevated, the offsite concentrations of the principal constituents of concern for both the organic sediment unit and the upper silty clay unit are, in most cases, anywhere from 1.4 to 75 times lower than the maximum onsite concentrations. The concentrations for the principal constituents of interest in the lower silty clay unit in the offsite ponds in the majority of cases were low (see Table 3.3) and below Ontario typical background concentrations along the approximate centre line of the three ponds (see Table 3.2).

3.4.3 Delineation and Volume of Contamination

Onsite Volumes

The impacted area within the onsite portion of Young's Creek Area has been delineated as the majority of the area south of the east tailings dam to Highway 7, and below the high water elevation of approximately 189 masl. SRK divided the Young's Creek Area into the four quadrants, denoted as the northwest, northeast, southwest, and southeast sectors, as shown in Figure 3-4 (SRK, 1998). Concentrations were compared to the MOE's PSQG and OWDG, and sampling locations that showed analytical results greater than the LEL for the indicator metals were included in the calculation of the area. Based on SRK data, total impacted surface area within the Young's Creek Area is identified as approximately 148,000 m^2. Upon further review of available sediment sampling data, it was noted that impacted sediment/soil was also present to the northeast of the northwest sector (see sample locations SD3019, 3020, 3021, and 4020 on Figure 3-3A). This additional area, denoted as the North Sector in Figure 3-4, was approximately 52,000 m^2. Thus the total area of impacted sediments onsite is approximately 200,000 m^2.

The estimated volumes of contaminated materials to be dealt with in any rehabilitation plan for the onsite portion of Young's Creek are discussed separately below for the highly contaminated organic/red mud sediments and the underlying lesser contaminated silty clay soils.

Volume of Highly Contaminated Organic Sediments. Geochemical investigations have found that contaminant concentrations of arsenic, copper, cobalt, and nickel are highest in the upper strata of sediment; that is, the organic and red mud layers (CH2M HILL, May 2001). In addition, the radiological survey indicated high gamma radiation and uranium concentrations in the red mud sediments, especially in the area immediately below the east tailings dam and northern portion of the Young's Creek floodplain (CG&S, June 1999). The depth of the organic/red mud layer varies across Young's Creek, from about 0.1 mbgs to 0.7 mbgs. Assuming that the most contaminated sediments are within the top 0.5 m of sediment, this results in a total volume of contaminated sediments of approximately 100,000 m^3. This represents a conservative estimate of the most contaminated sediments in the Young's Creek Area onsite.

Volume of Underlying Lesser Contaminated Silty Clay Soil. Although the most contaminated sediments are confined to the upper subsurface layers, contamination has been found to also extend into the deeper layers of silty clay. Through a review of the sediment sample data, the following assumptions were made as to the depth of contamination by the sectors identified by SRK.

- Samples taken in the northwest sector showed concentrations of arsenic, copper, and nickel that exceed their respective SEL criteria to at least 1.0 mbgs, while cobalt concentrations ranging between 100 μg/g and 110 μg/g have been detected exceeding the OWDG LEL at depths of at least 1.5 mbgs and are encountered sporadically at greater depths. It was assumed that contaminated sediments potentially extend to a depth of 1.5 mbgs in these sectors. (Note: The MRS determined a site specific screening level concentration [SLC] for cobalt of 296 μg/g, which is analogous to an LEL. Should this SLC be confirmed as a cleanup criterion, the volume of contaminated silty clay may be significantly reduced, assuming that metals in addition to the aforementioned indicator metals are not present at elevated concentrations at depth.)
- Samples taken in the northeast sector showed concentrations of arsenic, copper, and nickel exceeding their respective SEL criteria to at least 1.0 mbgs, but not at 1.5 mbgs. Consequently, it is assumed that contaminated sediments extend to a depth of 1.25 mbgs.

- Samples taken in the southwest, southeast and north sectors showed concentrations of arsenic, copper, and nickel exceeding their respective SEL criteria to at least 0.5 mbgs, but not at 1.0 mbgs. Consequently, it is assumed that contaminated sediments extend to a depth of 0.75 mbgs.

Based on these assumptions, approximately 99,000 m^3 of lesser impacted silty clay soil that may require management is present beneath the upper organic sediments in the onsite portion of Young's Creek.

Offsite Volumes

Estimates of the amount of impacted sediment exceeding either the SEL or LEL sediment quality criteria that will potentially require remediation or management for the offsite portion of Young's Creek were developed using the sampling data collected during the offsite investigation. The approximate area where impacted sediments were identified is shown in Figure 3-4. The sediment and silty clay thickness data and the analytical sampling data collected during the investigation was interpreted utilizing the computer mapping software package *SURFER for Windows* to produce sediment thickness plots and contaminant concentration contour maps. To calculate the volume of impacted sediment and the volume of impacted clay across all three ponds, *SURFER for Windows* was initially used to calculate a volume based on the sediment thickness plot and the silty clay thickness plot. Details are presented in CH2M HILL's report entitled *Delineation of Offsite Sediments and Clay Deposits in Young's Creek and Assessment of Beaver Dams*, March, 2003.

The volume of sediment was calculated for the upper organic sediment unit and for the combined upper and lower silty clay units using the cut and fill volume calculation features in *SURFER for Windows*. The volume of the upper organic sediment and the upper impacted silty clay unit was calculated using the volume information obtained with Surfer and by multiplying the average thickness of the upper organic sediment (0.3m) and the average thickness of the upper impacted silty clay unit (0.36 m) respectively, by the approximate surface area of all three ponds (188,550 m^2).

Table 3.4 provides an estimate of the volume of impacted sediment and underlying silty clay units for both the onsite and offsite areas of Young's Creek. For the offsite area, as noted in Table 3.4, approximately 60,000 m^3 of highly impacted upper organic sediment is present between all three ponds and approximately 70,000 m^3 of underlying silty clay (upper silty clay) that may also potentially require management is present.

Several assumptions were made for the purpose of calculating these estimates:

- The sediment thickness and silty clay thickness plots and corresponding volumes were calculated using *SURFER for Windows* with professional judgement as well as the average sediment thickness information based on the stratigraphic observations collected from a limited number of sampling locations during the investigation. Although the observations were considered to be representative of actual conditions, it should be recognized that sediment thickness data will vary between sampling locations.

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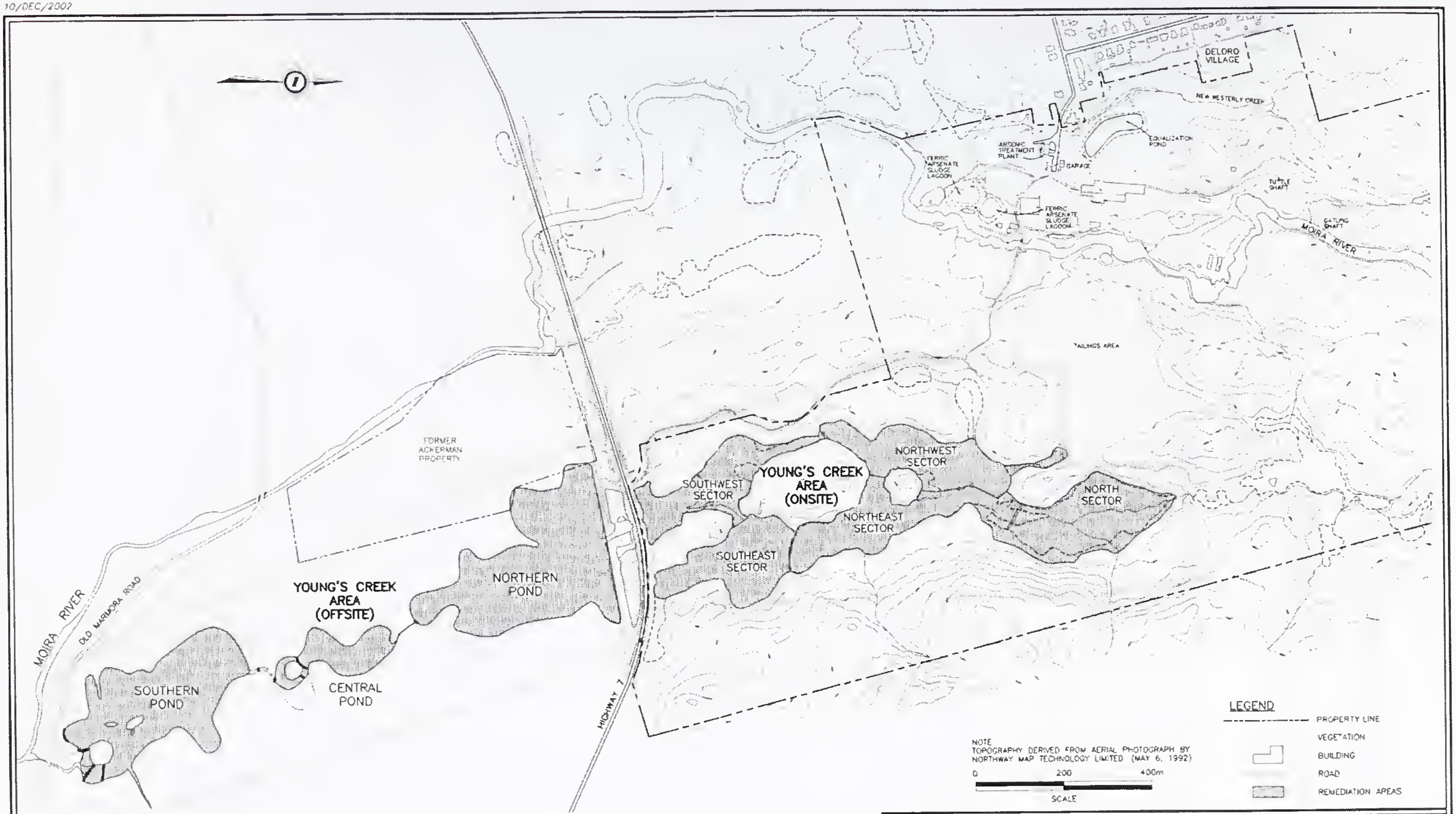

CH2MHILL

PROJECT No 119548

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-4
YOUNG'S CREEK
REMEDIATION AREAS

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- The volume of the most highly impacted upper organic sediment unit from all three ponds was calculated using an average thickness of approximately 0.3 m. The volume of the less impacted upper silty clay unit also potentially requiring remediation was calculated using an average thickness of 0.36 m.
- The volume estimates were prepared based on the assumption that the entire upper sediment unit across all three ponds is impacted above the applicable SEL or LEL criteria. It was also assumed that any remediation conducted on the silty clay unit can be restricted to the upper silty clay unit and exclude the lower silty clay unit. This assumption was based on the sampling data that indicated the lower silty clay unit in the majority of locations is below typical background conditions. It should be noted however, during actual remediation it may be difficult to differentiate between these two units in the field during remedial excavation.
- The estimated volume of sediment in all three ponds was based on the current extent of each pond and the current sampling data available. Volumes of sediment could potentially change positively or negatively based on a variety of factors such as increased sediment deposition from upstream, identification of additional impacted sediment, additional flooding of the area via beaver damming activities, washout of sediments downstream, etc.

Taking the assumptions noted above for the onsite and offsite sediments into consideration, and the areas estimated by SRK for the onsite sediments, the amounts of contaminated sediments in the Young's Creek Area by sector for onsite and by pond for offsite are shown in Table 3.4. The total amount of contaminated sediment in the onsite area is approximately is 199,000 m^3. In the offsite area approximately 60,000 m^3 of highly impacted upper organic sediment is present between all three ponds and approximately 70,000 m^3 of underlying silty clay (upper silty clay) that also may require management is present, for a combined total of 130,000 m^3. The overall total for the onsite and offsite sediments that may require management is 329,000 m^3.

TABLE 3.4
AMOUNT OF CONTAMINATED SEDIMENT IN *ONSITE* AND *OFFSITE* AREAS OF YOUNG'S CREEK

Sector/ Pond	Area (m2)	Assumed Thickness of Contamination (m)		Estimated Volume of Highly Impacted Sediments (m3)c	Estimated Volume of Less Impacted Sediment (m3)c	Total Volume of Impacted Sediments (m3)c
Onsite Area						
North	52,000	0.5[a]	0.25[b]	26,000	13,000	39,000
Northwest	39,740	0.5[a]	1.0[b]	20,000	40,000	60,000
Northeast	37,350	0.5[a]	0.75[b]	19,000	28,000	47,000
Southwest	33,980	0.5[a]	0.25[b]	17,000	9,000	26,000
Southeast	36,560	0.5[a]	0.25[b]	18,000	9,000	27,000
Total (Onsite)	**200,000**			**100,000**	**99,000**	**199,000**

TABLE 3.4
AMOUNT OF CONTAMINATED SEDIMENT IN *ONSITE* AND *OFFSITE* AREAS OF YOUNG'S CREEK

Sector/ Pond	Area (m2)	Assumed Thickness of Contamination (m)		Estimated Volume of Highly Impacted Sediments (m3)c	Estimated Volume of Less Impacted Sediment (m3)c	Total Volume of Impacted Sediments (m3)c
Offsite Area						
Northern Pond	94,150	0.3[a]	0.36[b]	29,000	35,000	64,000
Central Pond	19,250	0.3[a]	0.36[b]	7,000	8,000	15,000
Southern Pond	75,150	0.3[a]	0.36[b]	24,000	27,000	51,000
Total (Offsite)	**189,000**			**60,000**	**70,000**	**130,000**
TOTAL (Onsite & Offsite)	**389,000**					**329,000**

Notes:
[a] Assumed average thickness (m) of highly impacted upper organic sediment unit
[b] Assumed average thickness (m) of less impacted upper silty clay unit possibly requiring remediation
[c] Note that calculated volumes have been rounded.

3.4.4 Contaminant Loading

As indicated in Section 2.2, arsenic loading from the Young's Creek Area to the Moira River has been estimated to be approximately three percent (154 kg/yr) of the total arsenic load. In addition, a large volume of highly contaminated material that could be re-mobilized under flood conditions is exposed at ground surface in this area.

Cobalt loading from the Young's Creek Area to the Moira River has been estimated to be approximately two percent (13 kg/yr) of the total cobalt load and is primarily due to the red mud from this area (CH2M HILL, March 2002). Copper and nickel loadings contribute to the overall Moira River loadings to a much lesser extent.

3.5 Summary

Young's Creek consists of an onsite and offsite area. The onsite area is located to the east of the former Deloro Mine Site and the offsite portion is located south of Highway 7 to the confluence of Young's Creek and the Moira River. A portion of the Young's Creek Area in both the onsite and offsite portions has been identified as being impacted to varying degrees with arsenic, cobalt, copper, and nickel compounds. The onsite portion of Young's Creek south of the east tailings dam and north of Highway 7 has been identified as being the most impacted. Concentrations in both the organic sediment unit and the upper silty clay unit, in most cases, were anywhere from 1.0 to 75 times higher in the onsite portion of Young's Creek than the maximum offsite concentrations. In addition, while offsite samples were found to be consistent with or below background radiation levels for the area, low-level radioactivity was detected for some onsite sediments. The contamination onsite is widespread within the upper 0.5-m of the red mud and organic sediments of the flood basin. The contamination extends deeper into the silty clay layer in the northern half of this area. It has already been identified that the concentrations of seven metals in addition to arsenic, cobalt, copper, nickel, lead, uranium, and silver were also detected at elevated concentrations onsite; however, no sampling was performed for analysis of these metals as part of the offsite investigation. These metals will nonetheless be evaluated as part of the Site Specific Risk Assessment. The source of this contamination has likely been the occasional historical releases and continuous seepage from the Tailings Area. In the offsite portion of Young's Creek, the most heavily impacted sediments are present in the upper organic sediment unit with an average thickness of 0.3 m.

Contaminated sediments that exceed the MOE's Severe Effect Level (SEL) are present in both the onsite and offsite areas of Young's Creek, which means there is potential for harmful impacts to the local aquatic and terrestrial ecosystems. A further hazard to human health is posed by the potential for re-mobilization of the contaminated sediments during flooding events, which will result in high contaminant loadings to the Moira River.

In addition to the contaminated sediments, a low-level radioactive field exists in the onsite portion of Young's Creek, which may pose a human health or ecological hazard both as it exists in place as well as via suspended particulate from dried radioactive sediment. Since this low-level radioactivity is considered to be associated with the contaminated sediments, addressing the issue of contaminated sediments will also address the issue of low-level radioactivity.

The selected remediation alternative will need to address the hazards to the local ecology as well as to the Moira River. These concerns have been incorporated into the evaluation of the rehabilitation alternatives.

Based on the sampling data available, as presented in this section, the total amount of contaminated sediment in the onsite area that will likely require management is 199,000 m^3. In the offsite area, approximately 60,000 m^3 of highly impacted upper organic sediment is present between all three ponds and approximately 70,000 m^3 of underlying silty clay (upper silty clay) is present, totaling 130,000 m^3 of material in the offsite area that will likely require management. The overall total for the onsite and offsite sediments that will likely require management is 329,000 m^3.

4. Alternatives Evaluation Process

4.1 Strategic Direction for Site Cleanup

In the early 1990s, MOE staff from Southeast Region (now MOE Eastern Region) reviewed the Deloro Mine Site Project with the then MOE Management Committee to determine a strategic direction for final site cleanup. The Committee was composed of several MOE Assistant Deputy Ministers (ADMs), the Deputy Minister (DM) and the Minister, as well as an ADM and Director from the Ministry of Northern Development and Mines (MNDM).

Based on a detailed analysis of site conditions and on previous experience gained in similar situations, the Committee recommended that onsite waste management options be favoured as primary remediation techniques to rehabilitate the site. The main reason for adopting this approach was the realization that complete cleanup to natural background levels would be extremely costly and may not represent the most prudent expenditure of public funds. It was also recommended that the cleanup work proceed under an exemption to the provincial Environmental Assessment Act. These two recommendations were endorsed by the Ontario Minister of the Environment in October 1991 and funds were then allocated to retain professional services to develop and implement a cleanup plan under the authority of the MOE. The latter recommendations were identified as "fundamentals" in the *Deloro Rehabilitation Plan* produced by the Southeast Region office of the MOE (now the Eastern Region office of the MOE) in September 1992 and formed an integral part of the request for proposal that was issued by the MOE in 1996 to select a consulting engineering firm to develop and implement a remedial plan for the Deloro Mine Site.

4.2 Closure Objectives

As described in the report entitled *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a), and in the above section, the strategic direction for site cleanup involves onsite management of wastes through isolation and containment methods as primary remediation techniques. Consequently, a pragmatic approach has been adopted where mitigative measures are directed at risk reduction. This translates into the following project objective:

> *To successfully rehabilitate the Deloro Mine Site to mitigate any unacceptable impacts on human health or the environment in compliance with relevant environmental policies and regulations*

To satisfy this objective, specific site-wide and distinct area closure objectives were developed. The site-wide closure objectives are as follows:

1. Reducing the loading of arsenic and other contaminants to the Moira River
2. Compliance with appropriate regulations and policy
3. Satisfy the general intent of the Mining Act and related draft regulations
4. Reducing/controlling impact/risk to acceptable levels
5. Demolition of unneeded buildings to ground level

6. Prioritizing remedial action implementation according to risk reduction
7. Minimizing perpetual operation and maintenance
8. Restoration of the site to reflect its natural surroundings
9. Securing the site for the indefinite future
10. Managing the wastes over the smallest possible area

These site-wide closure objectives were further refined into area-specific closure objectives for each of the areas of the site. The area-specific closure objectives for the Young's Creek Area are presented in Section 5.1.

4.3 Overview of the Process to Generate and Evaluate Alternatives

The process applied by CH2M HILL to generate potential remedial alternatives for all areas of the Deloro site is illustrated in Figures 4-1 to 4-3. Initially, conceptual remediation methods that could have addressed some or all of the issues identified for each respective area of the site were identified. For instance, a method may address groundwater issues but not impacted sediment. These methods were evaluated with a screening process to identify which methods had the greatest potential to address the issues at the site, either alone or in combination with other methods. Improbable methods that did not have significant potential to contribute to a viable solution were eliminated early in the process. This resulted in a list of primary remediation methods that were retained for further evaluation.

The primary remediation methods were combined with enhancing features based on the judgement and experience of the project team to create a number of comprehensive remediation alternatives that addressed all of the environmental issues at the site. These comprehensive remediation alternatives were subsequently evaluated in a two-step process. The screening level evaluation again served to eliminate comprehensive remediation alternatives (as opposed to conceptual remediation methods that have been previously screened) that were unlikely to meet all of the remediation needs for the area. This second level of screening led to a short list of comprehensive remediation alternatives that were the subject of a more detailed evaluation. The detailed evaluation led to the identification of a recommended remediation alternative, which would be developed further and subsequently implemented to address the environmental issues at the site.

4.4 Generation of Comprehensive Remediation Alternatives

Significant efforts were invested through the years to characterize environmental conditions (i.e. soil, surface water, groundwater, air, human health risk, and ecological conditions) for all areas of the site. Such characterization studies were necessary to identify contaminants of concern, quantify contaminant concentrations and volumes, determine the media into which the contaminants were found, and assess contaminant mobility. It is as a function of these characteristics that potential conceptual remediation methods were initially generated.

The alternatives generation process involved consideration of the strategic approach described in Section 4.1, identification of conceptual remedial methods that CH2M HILL has either used on similar projects in the past, or identified in the scientific literature for the contaminants and media of concern, as well as specific exclusionary criteria dealing with the following:

- Effectiveness of the conceptual methods in question to remediate the site
- Satisfaction (in principle) of government regulations and guidelines
- Pre-established design closure criteria

These criteria were designed to eliminate improbable conceptual remediation methods early in the process so that valuable time and resources were not expended in the completion of a more detailed evaluation.

The methods developed for consideration were not intended to be an exhaustive evaluation of all conceivable methods, but a focused assessment of readily identifiable and proven methods that had good potential for successful application at the site. Consideration of experimental or developmental methods was considered beyond the scope of this evaluation. Professional judgement and practical considerations factored into the range and diversity of methods considered. For instance, where a proven and effective method was readily identifiable and cost-effective, limited consideration was made of other methods.

The first exclusionary criterion, the effectiveness of the conceptual remediation method, was used to evaluate the expected effectiveness of the method in solving the problem identified for the area (i.e. Can the conceptual remediation method contribute to a significant attenuation of unacceptable impacts on human health or the environment by way of reducing a component of the contaminant load?). The second criterion, the satisfaction of government regulations and guidelines, served to evaluate the capacity of the conceptual remediation method to meet relevant government legislation and guidelines. The third criterion, design closure criteria, was used to assess whether the conceptual remediation method was likely to satisfy the area specific design criteria, a combination of the closure criteria and remediation targets outlined below.

These design criteria were developed from a risk based approach that is summarized in the report entitled *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a). The risk based approach was used to identify areas of the site that pose the greatest risk and consequently served to prioritize remedial action to obtain the greatest reduction of contaminant release from the site as well as overall exposure to contaminants. Using risk assessment, remediation targets were set as follows:

1. Surface water from Young's Creek and the Moira River should satisfy, on average, the Interim Provincial Water Quality Objectives (PWQO) for three key contaminants (i.e. arsenic, cobalt and copper) at the Highway 7 crossing located approximately 600 m downstream (i.e. south) of the site.

2. Post-closure onsite arsenic concentration in air and soil should be, on average, below a concentration that will ensure that the probability of incremental lifetime cancer risk for onsite workers and potential recreational users of the site is less than 1:100,000.

To achieve these targets, site-wide closure objectives were translated to area-specific closure objectives (as stated in Section 5.1) that were refined into closure criteria that specifically address the following:

- Physical aspects
  - Design service life
  - Design floods
  - Seismic considerations
  - Minimum factors of safety
  - Perpetual disruptive forces
- Chemical aspects
  - Human health
  - Aquatic life
  - Terrestrial habitat
- Radiological aspects

These closure criteria will become closure plan design parameters for the selected remediation alternative, as described in the *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a).

4.4.1 Screening of Conceptual Remediation Methods

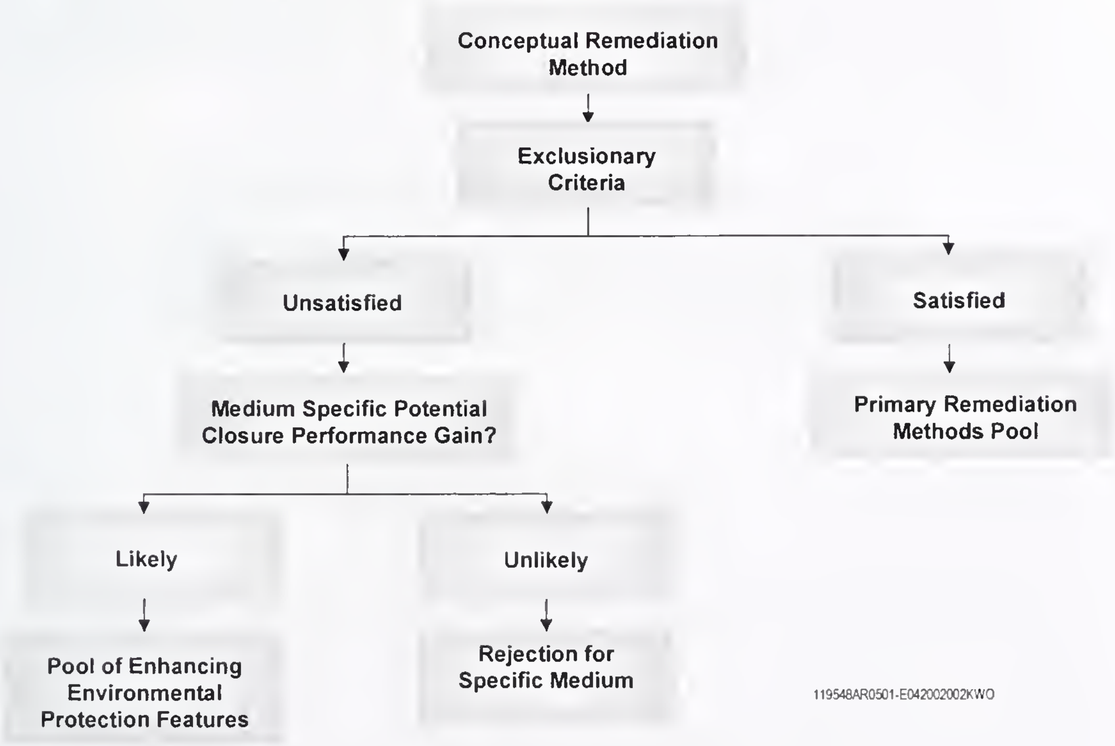
Each conceptual remediation method was consequently evaluated to determine whether it could (yes) or could not (no) meet the exclusionary criteria presented above. A "no" to any of these criteria eliminated the conceptual remediation method as a primary remediation method. A primary remediation method is defined as a method that had significant potential to address most of the environmental issues in this area of the site without further augmentation or enhancement. All criteria carried equal weight in the evaluation process; therefore, their order of appearance does not reflect their relative importance. Table 4.1 further synthesizes the intent of the exclusionary criteria used to generate remediation alternatives.

TABLE 4.1
EXCLUSIONARY CRITERIA – SCREENING OF CONCEPTUAL REMEDIATION METHODS

Exclusionary Criteria	Considerations	Measure
Effectiveness	Does the conceptual remediation method have the potential to solve one or more aspects of the problem? (i.e. Can it contribute to a significant attenuation of any unacceptable impacts on human health or the environment by way of reducing a component of the contaminant load?)	Yes – The conceptual remediation method has the potential to significantly reduce contaminant loads to the environment. No – The conceptual remediation method does not have the potential to significantly reduce contaminant loads to the environment.
Government Regulations and Guidelines	Does the conceptual remediation method conform in principle to applicable government regulations and guidelines relating to site rehabilitation? (e.g. Guideline for Use at Contaminated Sites, Mining Act and Rehabilitation Guidelines?)	Yes – The conceptual remediation method is more likely to conform. No – The conceptual remediation method is less likely to conform.
Design Closure Criteria	Is the conceptual remediation method likely to satisfy design closure criteria pertaining to site specific risk assessment of human health and environmental impacts if developed in greater detail?	Yes – The conceptual remediation method has the potential to satisfy design criteria. No - The conceptual remediation method has no potential to satisfy design criteria.

Rejection as a primary remediation method did not exclude further consideration of the method to augment another conceptual remediation method, particularly if the former showed significant potential to control the release or minimize the mobility of contaminants in a specific medium (groundwater, surface water, soil or air). Some methods were retained based on their potential for combination with other methods to create a comprehensive solution to the environmental issues in an area. Such combinations were termed "Comprehensive Remediation Alternatives". Other methods were retained as potential enhancements, which formed redundancies in the design, such as multiple barriers to contaminant release/migration. Figure 4-1 illustrates the process used to screen conceptual remediation methods.

FIGURE 4-1
SCREENING OF CONCEPTUAL REMEDIATION METHODS – SCHEMATIC DIAGRAM

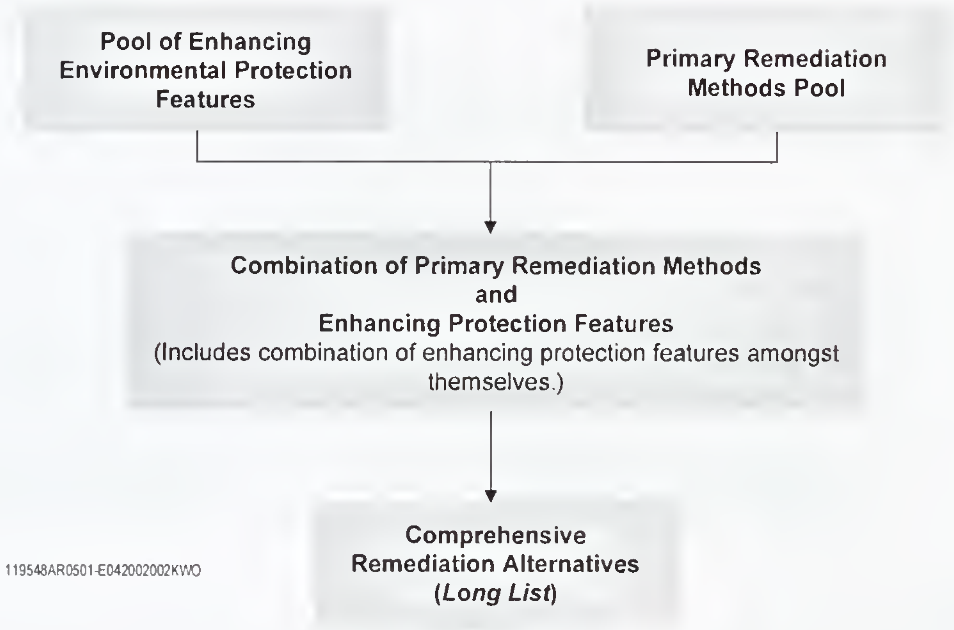

Conceptual Remediation Method
Exclusionary Criteria
Unsatisfied
Satisfied
Medium Specific Potential Closure Performance Gain?
Primary Remediation Methods Pool
Likely
Unlikely
Pool of Enhancing Environmental Protection Features
Rejection for Specific Medium
119548AR0501-E042002002KWO

4.4.2 Development of Comprehensive Remediation Alternatives

Figure 4-2 schematically illustrates the process used to generate comprehensive remediation alternatives for further consideration. Alternatives were developed from the list of primary remediation methods that have passed the screening level evaluation. Comprehensive remediation alternatives were developed to create potential solutions that addressed all of the environmental issues or problems in each area. Where primary remediation methods have been identified through the screening process, the team considered how the method could be augmented or enhanced to address all the issues. In developing comprehensive remediation alternatives, the project team considered the multiple goals and objectives that must be achieved for an acceptable solution. In particular, comprehensive remediation alternatives were developed to mitigate the release of contaminants to the environment along various exposure or migration pathways.

In addition to developing comprehensive remediation alternatives that just meet the project requirements, our team has also considered augmenting or enhancing these alternatives to provide greater certainty through additional levels of protection. These enhancing environmental protection features were considered as design redundancies or contingencies that provide multiple barriers to contaminant release/migration and serve to increase the level of confidence that an alternative will achieve the project goals.

FIGURE 4-2
DEVELOPMENT OF COMPREHENSIVE REMEDIATION ALTERNATIVES – SCHEMATIC DIAGRAM


Pool of Enhancing Environmental Protection Features
Primary Remediation Methods Pool
Combination of Primary Remediation Methods and Enhancing Protection Features (Includes combination of enhancing protection features amongst themselves.)
Comprehensive Remediation Alternatives (*Long List*)
119548AR0501-E042002002KWO

4.5 Evaluation of Comprehensive Remediation Alternatives

The evaluation process that was developed to select a recommended remediation alternative for the area of the site relied on a qualitative assessment of the comprehensive remediation alternatives. It allowed the evaluation to focus on the alternatives that are most promising to satisfy the closure objectives while avoiding consideration of superfluous alternatives.

Comprehensive remediation alternatives were evaluated using the process illustrated in Figure 4-3. The first step in selecting a recommended remediation alternative was to compare all comprehensive remediation alternatives (the "long list") to a second set of exclusionary criteria identified in Table 4.2 as a screening exercise. This step ensured that the combination of an environmental protection feature with a primary remediation method did not undermine the potential effectiveness of the latter. The exercise led to the construction of a "short list" of comprehensive remediation alternatives from which the recommended remediation alternative was selected. It is important to recognize that while the first set of exclusionary criteria shown in Table 4.1 deals mainly with the evaluation of *methods* which have the potential to form *part* of a comprehensive solution, such as reduction of a component of contaminant load to the environment, the second set of exclusionary criteria shown in Table 4.2 focuses on the screening of *comprehensive solutions* and their ability to achieve an overall reduction of contaminant load from the area.

TABLE 4.2
EXCLUSIONARY CRITERIA - SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Exclusionary Criteria	Considerations	Measure
Effectiveness	Does the comprehensive remediation alternative solve the problem? (i.e. Can it contribute to a significant attenuation of any unacceptable impacts on human health or the environment by way of reducing contaminant loads from the entire Area?)	Yes – The comprehensive remediation alternative has the potential to significantly reduce contaminant loads to the environment. No – The comprehensive remediation alternative does not have the potential to significantly reduce contaminant loads to the environment.
Government Regulations and Guidelines	Does the comprehensive remediation alternative conform to applicable government regulations and guidelines relating to site rehabilitation? (e.g. Guideline for Use at Contaminated Sites, Mining Act and Rehabilitation Guidelines)	Yes – The comprehensive remediation alternative is more likely to conform. No – The comprehensive remediation alternative is less likely to conform.
Design Closure Criteria	Will the comprehensive remediation alternative satisfy design closure criteria pertaining to site specific risk assessment of human health and environmental impacts?	Yes – The comprehensive remediation alternative has the potential to satisfy design criteria. No – The comprehensive remediation alternative has no potential to satisfy design criteria.

The detailed evaluation of the short-listed comprehensive remediation alternatives was completed by comparing them against a series of evaluation criteria that not only reflected the objectives of the project but that also captured the essence of environmental assessment criteria that are commonly applied by the MOE when it is required to evaluate impacts associated with a given project. Appendix A illustrates how the detailed evaluation criteria used in the process described here and the environmental assessment screening criteria are related.

The detailed evaluation criteria consist of four categories of criteria listed below. All criteria carry equal weight in the evaluation process and consequently their order of appearance does not reflect the relative importance of each criterion.

- Technical Considerations
  - Reliability
  - Compatibility with existing system
  - Ease of implementation

- Costs
  - Operation and maintenance costs
  - Capital costs

- Social Considerations
  - Public acceptance
  - Risk to public
  - Constraint for recreational use
  - Negative impact to private properties
  - Visual character of the area
  - Risk to workers

- Natural Environment
  - Geochemistry
  - Terrestrial habitats
  - Floodplain
  - Fish habitats

Table 4.3 summarizes the intent of the detailed evaluation criteria. Further descriptions of each category of criteria are provided below.

TABLE 4.3
DETAILED EVALUATION CRITERIA – COMPREHENSIVE REMEDIATION ALTERNATIVES

Criteria	Considerations	Measure
Technical Considerations		
Reliability	Ability of the alternative to satisfactorily control discharge quality on a regular and reliable basis	Good - very reliable, few performance problems Fair - somewhat reliable, some performance problems Poor - not reliable, many performance problems
Compatibility with Existing System	Ability of the alternative to adapt to the existing site conditions and system	Good - very compatible, few technical problems Fair - somewhat compatible, some technical problems Poor - not compatible, many technical problems
Ease of Implementation	Ability of the alternative to be easily implemented from a technical perspective (e.g. land availability, timing, approval requirements)	Good - easily implemented, few problems Fair - somewhat easily implemented, some problems Poor - not easily implemented many problems encountered
Costs		
Operation & Maintenance Costs	Relative measure of O&M costs compared to other alternatives	High - relatively high operating and maintenance costs Moderate - relatively moderate operating and maintenance costs Low - relatively low operating and maintenance costs
Capital Costs	Relative measure of capital costs compared to other alternatives	High - relatively high capital costs Moderate - relatively moderate capital costs Low - relatively low capital costs
Social Considerations		
Public Acceptance	The potential for the comprehensive remediation alternative to be accepted by the public	High - minimal or no potential for some reservation from the public Moderate - potential for some reservation from the public Low - potential for significant reservation from the public

TABLE 4.3
DETAILED EVALUATION CRITERIA – COMPREHENSIVE REMEDIATION ALTERNATIVES

Criteria	Considerations	Measure
Risk to Public	The potential for the comprehensive remediation alternative to create a risk to public safety	High – potential for significant risk to public safety Moderate - potential for some risk to public safety Low – potential for low/no risk to public safety
Constraint for Recreational Use	The potential for the comprehensive remediation alternative to create constraints for recreational opportunities	High – potential for significant constraints on recreational opportunity Moderate - potential for some constraints on recreational opportunity Low – minimal or no constraints for recreational opportunity
Negative Impact to Private Properties	The potential for the comprehensive remediation alternative to produce a negative impact to private properties	High – potential for significant negative impact to surrounding private properties Moderate - potential for some negative impacts on surrounding private properties Low – minimal or no negative impacts on surrounding private properties
Visual Character of the Area	The potential for the comprehensive remediation alternative to impact the visual character of the area	High – potential to severely impact the visual character of an area Moderate - potential to have some impacts on the visual character of an area Low – minimal impacts on the visual character of an area
Risk to Workers	The potential for the comprehensive remediation alternative to create a risk to workers	High – potential for significant risk to workers Moderate - potential for some risk to workers Low - potential for low/no risk to workers
Natural Environment		
Geochemistry	The potential for the alternative to improve the geochemistry of the area	High - high potential to improve the geochemistry Moderate - some potential to improve the geochemistry Low - low potential to improve the geochemistry
Terrestrial Habitats	The potential of an alternative to improve terrestrial habitats	Good - potential to significantly improve terrestrial habitats Fair - potential to somewhat improve terrestrial habitats Poor - minimal or no improvement to terrestrial habitats
Floodplain	The potential of the alternative to disrupt/intrude upon the floodplain	High – potential to disrupt/intrude upon floodplain resulting in potentially significant impacts to the system. Moderate - potential to cause some disturbance or intrusion into floodplain; impacts less severe Low – minimal/no disturbance; alternative offers the opportunity to "cleanup" floodplain.
Fish Habitats	The potential of the alternative to cause disturbance to or loss of fisheries habitat	High - potential to cause disturbance or loss of significant area of fisheries habitat, significant compensation measures required; Moderate - potential to cause some disturbance or loss of fisheries habitat, some mitigation required; Low - minimal disturbance or no loss of fisheries habitat

4.5.1 Technical Considerations

The first technical criterion dealt with the comprehensive remediation alternative's technical reliability in mitigating human health and environmental impacts from the area. Surface water runoff and/or groundwater discharge have been identified as the main loading sources for the influx of arsenic and metals to the Moira River and Young's Creek. The ability to reduce the contact between the groundwater and the wastes or redirect the groundwater cross flow along with other water inputs to the area also form the basis for the evaluation of the comprehensive remediation alternative's reliability. The ability of the alternative to satisfactorily control discharge on a regular and reliable basis over the long term was considered paramount. These discharges and water inputs can be reduced by selecting or combining some of the following design principles:

- Reducing the amount of precipitation that infiltrates into the impacted materials
- Reducing the amount of groundwater contacting the impacted materials
- Lowering the static groundwater table below the lower horizon of impacted materials
- Intercepting surface water runoff and divert the flow away from the impacted materials
- Minimizing the onsite retention time of any uncontaminated water
- Reducing the contact area of the impacted materials
- Placing the wastes above the water table
- Reducing the rate at which water moves through the wastes

The second criterion examined the comprehensive remediation alternative's ability to operate in tandem with existing systems operating at the site, if present, notably the existing groundwater pumping and arsenic treatment system in the Industrial Area.

Finally, the ease to construct and implement the comprehensive remediation alternative was examined as a precursor to following criteria. Issues such as sufficient workspace, available technologies and complexity were addressed.

4.5.2 Costs

The second category of criteria used for the evaluation of rehabilitation alternatives was costs. Capital, construction, and operation and maintenance costs (O&M) for the comprehensive remediation alternatives were considered relative to each other. Costs were based upon the engineering complexity and work required to implement the alternative.

Costs were estimated on the basis of conceptual remediation plans derived from the conceptual remediation alternatives identified earlier in this process. Budgetary estimates were calculated for this evaluation process and meant to provide an indication of the magnitude of the cost associated with each comprehensive remediation for comparison purposes only. The cost estimates are presented in 2002 dollars.

4.5.3 Social Considerations

Criteria in this category addressed the ability of the remediation alternatives to meet social needs and expectations such as future recreational use of the property, impacts of the works on private property and the overall visual character of the site.

An important step in evaluating the alternatives was the ability to mitigate the threat to human health. The risk to human health was considered for the general public, rehabilitation staff and workers involved in ongoing operation and maintenance of the site, based on the potential for acute and long-term effects.

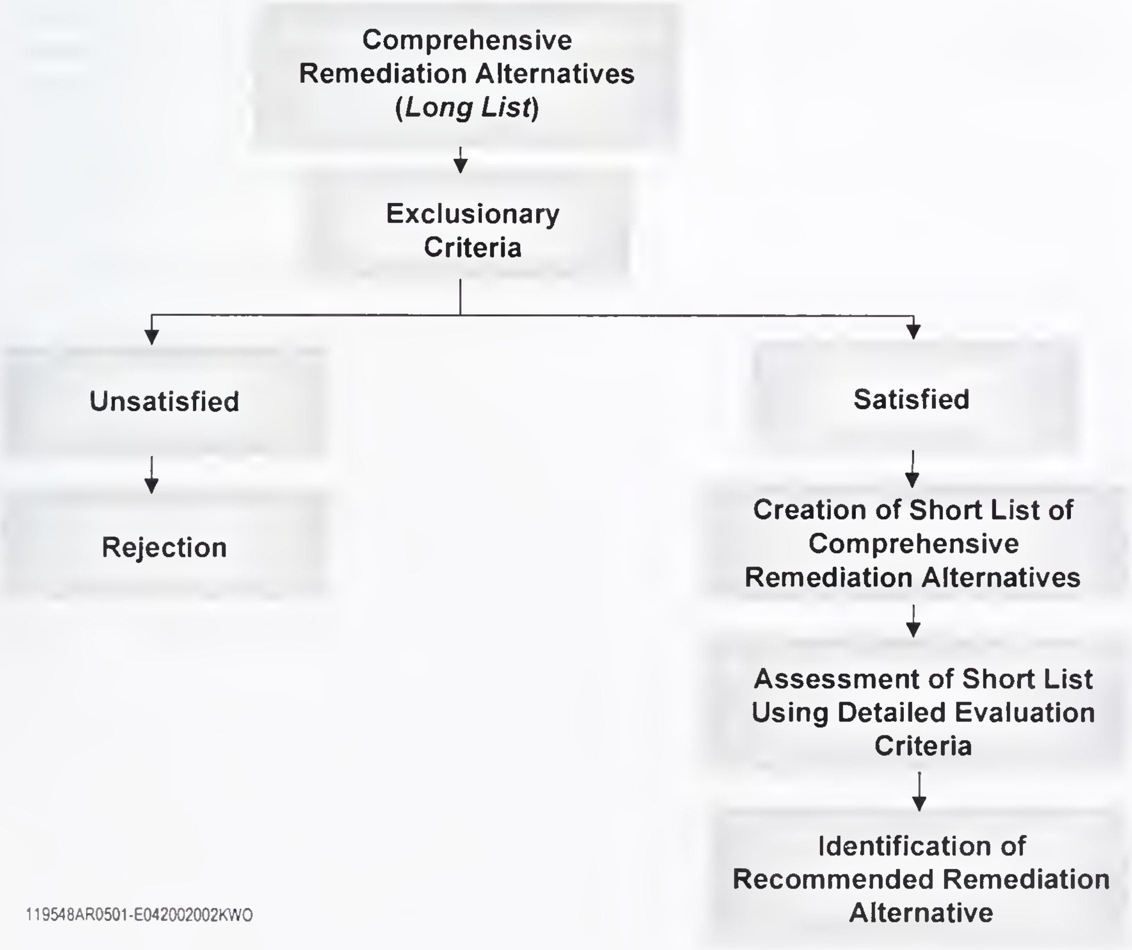
4.5.4 Natural Environment

This category encompasses all of the natural environmental components not covered in the above subsection. This evaluation examined the alternative's ability to improve or protect the following:

- Geochemistry (Surface water and groundwater quality)
- Terrestrial habitats
- Floodplains
- Fish habitats

Figure 4-3 schematically illustrates the process used for the detailed evaluation of the short-listed comprehensive remediation alternatives to determine the recommended remediation alternative.

FIGURE 4-3
EVALUATION OF COMPREHENSIVE REMEDIATION ALTERNATIVES – SCHEMATIC DIAGRAM


Comprehensive Remediation Alternatives (*Long List*)
Exclusionary Criteria
Unsatisfied
Rejection
Satisfied
Creation of Short List of Comprehensive Remediation Alternatives
Assessment of Short List Using Detailed Evaluation Criteria
Identification of Recommended Remediation Alternative
119548AR0501-E042002002KWO

4.6 Summary

The strategic direction of the Deloro Mine Site Cleanup Project in the early 1990s was to manage wastes onsite. Based on the overall project objective, which is to mitigate any unacceptable impacts on human health and the environment, a process was developed to generate "reasonable" comprehensive remediation alternatives for the area. The system relied on the use of exclusionary criteria to identify conceptual remediation alternatives that may be applicable for the area. It also allowed for the development of enhancing environmental protection features that could augment the level of protection offered by any given remediation alternative.

Following the generation of a long list of comprehensive remediation alternatives, each alternative was evaluated against two sets of criteria to identify a recommended remediation alternative. This evaluation of the alternatives against the first set of criteria resulted in a short list of comprehensive remediation alternatives that was evaluated in greater detail using the second set of criteria (i.e. the detailed evaluation criteria). The latter criteria provided a more detailed level of comparison of each alternative with respect to the others and allowed the selection of a recommended remediation alternative for the area.

An alternative was recommended that satisfied the greatest number of criteria and provided the greatest value to MOE based on the professional judgement of the CH2M HILL team.

5. Development and Evaluation of Alternatives

Comprehensive remediation alternatives to address contaminated sediments in the Young's Creek Area are developed and evaluated in this section. The development and evaluation of alternatives is completed using the process described in Section 4.

The remedial and closure objectives for both the overall Deloro site as well as for the Young's Creek Area are stated below. The remedial alternative ultimately selected for the Young's Creek Area should be consistent with these objectives.

5.1 Remedial and Closure Objectives

The overall remedial objectives for the Deloro site are stated in Section 4.2. Area-specific objectives were developed for the Industrial, Tailings and Mine Areas in the *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a). Specific closure objectives for the Young's Creek Area are stated below. These objectives are consistent with the specific objectives developed for the other areas of the site, specifically the Tailings Area. Closure objectives specific to the Young's Creek Area include:

1. Develop a rehabilitation closure plan supported by a Site Specific Risk Assessment (SSRA)
2. Develop/implement risk reduction plans according to site-wide priorities
3. Implement measures to reduce potential exposure of contaminated sediments to human and environmental receptors
4. Implement measures to prevent increased contaminant loading to the Moira River due to re-suspension of residual contaminated material
5. Restore area to match surrounding conditions and in accordance with Ministry of Natural Resources (MNR) policies and requirements
6. Design life for engineered facilities consistent with accepted design practices

5.2 Identification of Conceptual Remediation Methods

The long list of conceptual remediation methods to address contaminated sediments in the Young's Creek Area is developed in this section. During the identification process, certain types of remediation methods have been excluded based on the strategic direction for site rehabilitation that is discussed in detail in Section 4. The strategic direction establishes that the overall site rehabilitation should focus on onsite management rather than offsite management. Therefore, remediation methods requiring offsite management components, including offsite disposal and offsite treatment, are not included in the long list of conceptual remediation methods. Instead, remediation methods with an offsite management component will be used, if appropriate, to enhance or improve any primary onsite method.

Additionally, the "Do Nothing" alternative, which is commonly included in a remedial alternative evaluation, has not been included in the long list, but will instead be used as a benchmark against which other remediation methods are assessed. It is realized that the "Do Nothing" alternative does not address any of the specific closure objectives.

An SSRA has also been excluded from the long list as the levels of contamination are sufficiently high that an SSRA alone would not meet the risk targets for the site. An SSRA will be completed for the entire site once the preferred alternative has been selected for each of the four major areas to confirm that the appropriate level of risk reduction has been achieved. This is consistent with the first closure objective for the Young's Creek Area, which states that the preferred remedial alternative will be supported by an SSRA.

The long list of potential conceptual remediation methods to address contaminated sediments within the Young's Creek Area includes the following:

- Shallow Excavation of Highly Contaminated Sediments and Disposal Onsite
- Shallow Excavation of Highly Contaminated Sediments and Onsite Treatment
- Deep Excavation of Highly Contaminated Sediments and Underlying Contaminated Silty Clay Soil and Disposal Onsite
- In-Place Capping of Contaminated Sediments
- Creek Rehabilitation
- Flow Diversion Away from Most Highly Contaminated Sediments
- Flow Regulation in the Contaminated Portion of the Young's Creek Area

Each of these conceptual remediation methods is discussed in more detail below.

5.2.1 Shallow Excavation (of Highly Contaminated Sediments) and Disposal Onsite

This method consists of excavating the upper most highly contaminated organic and red mud sediments and disposing of these sediments in a secure onsite storage cell. For the onsite portion of Young's Creek, these sediments primarily exist within the upper 0.5 m of sediment. The estimated volume of these highly contaminated sediments in the onsite portion of the Young's Creek Area is 100,000 m^3, as shown in Table 5.1. For the offsite portion of Young's Creek, these sediments exist, on average, within the upper 0.3 m, although at some locations, contaminated sediment can be found as deep as 2 m. The estimated volume of these highly contaminated sediments in the offsite portion of the Young's Creek Area is 60,000 m^3, resulting in a total volume of 160,000 m^3.

TABLE 5.1
CONTAMINATED SEDIMENTS IN YOUNG'S CREEK AREA

Location	Average Thickness (m)	Volume (m^3)	As Concentration (µg/g) High/Average	Sediment/ Soil Type
Onsite	0.5 m	100,000	110,000/16,500	**Sediment**: Red silt/organic sediment
Onsite	0.25 to 1.0 m	99,000	7,500/1,971	**Soil**: Inorganic silty clay
Offsite	0.3 m	60,000	1,460/325	**Sediment**: Black org. peat/silt
Offsite	0.36 m	70,000	666/49	**Soil**: Inorganic silty clay

If this option was considered alone, with no further action or enhancements, this alternative would rely on natural sedimentation of non-contaminated sediments to replace the excavated material and cover the residual contamination left behind. This alternative would rely on natural processes to re-establish the natural ecology of the Young's Creek Area. With respect to onsite disposal options, the following locations have been identified. These include the Industrial Area, the Tailings Area, and within the Young's Creek Area itself.

Disposing of the contaminated sediments in the Industrial Area involves consolidating wastes in the area and covering the disposal area with an engineered cover designed to minimize infiltration. The Industrial Area is approximately 16,000 m^2, with the available disposal area extending across the southeast part of the area. The disposal area has capacity for approximately 113,000 m^3 of waste material. It is estimated that there is approximately 95,000 m^3 of identified waste material in the Industrial Area to be disposed of, leaving 18,000 m^3 of space for other currently unidentified wastes in the Industrial Area, or waste materials from other areas of the site such as Young's Creek. This is not enough space for the contaminated sediments identified in the Young's Creek Area and there are numerous technical limitations with extending the disposal area in the Industrial Area to accommodate additional wastes. These limitations include topography, slope, the need to maintain the perimeter drain, proximity to the Village of Deloro, and thickness of the cap. The stated preference of Deloro residents is that wastes not be moved closer to the village. Consequently, placing the total volume of the most highly contaminated sediments, from both the onsite and offsite portions of the Young's Creek Area, in the Industrial Area is not technically feasible, and would therefore not meet the design criteria.

The Tailings Area is approximately 80,000 m^2, and a potential alternative for remediating the area is a vegetated soil cover. Given the large area, it is potentially feasible to use some or all of the contaminated sediments from Young's Creek as cover for the Tailings Area. However, because the contaminated sediments found in the upper 0.5-m of Young's Creek contain a large amount of organic material, placing these sediments beneath a soil cover in the Tailings Area may lower the redox potential in the pore water and, in doing so, could liberate additional arsenic into solution (SRK, 1998). Therefore, disposal in the Tailings Area is not considered an effective option and is not recommended for further assessment.

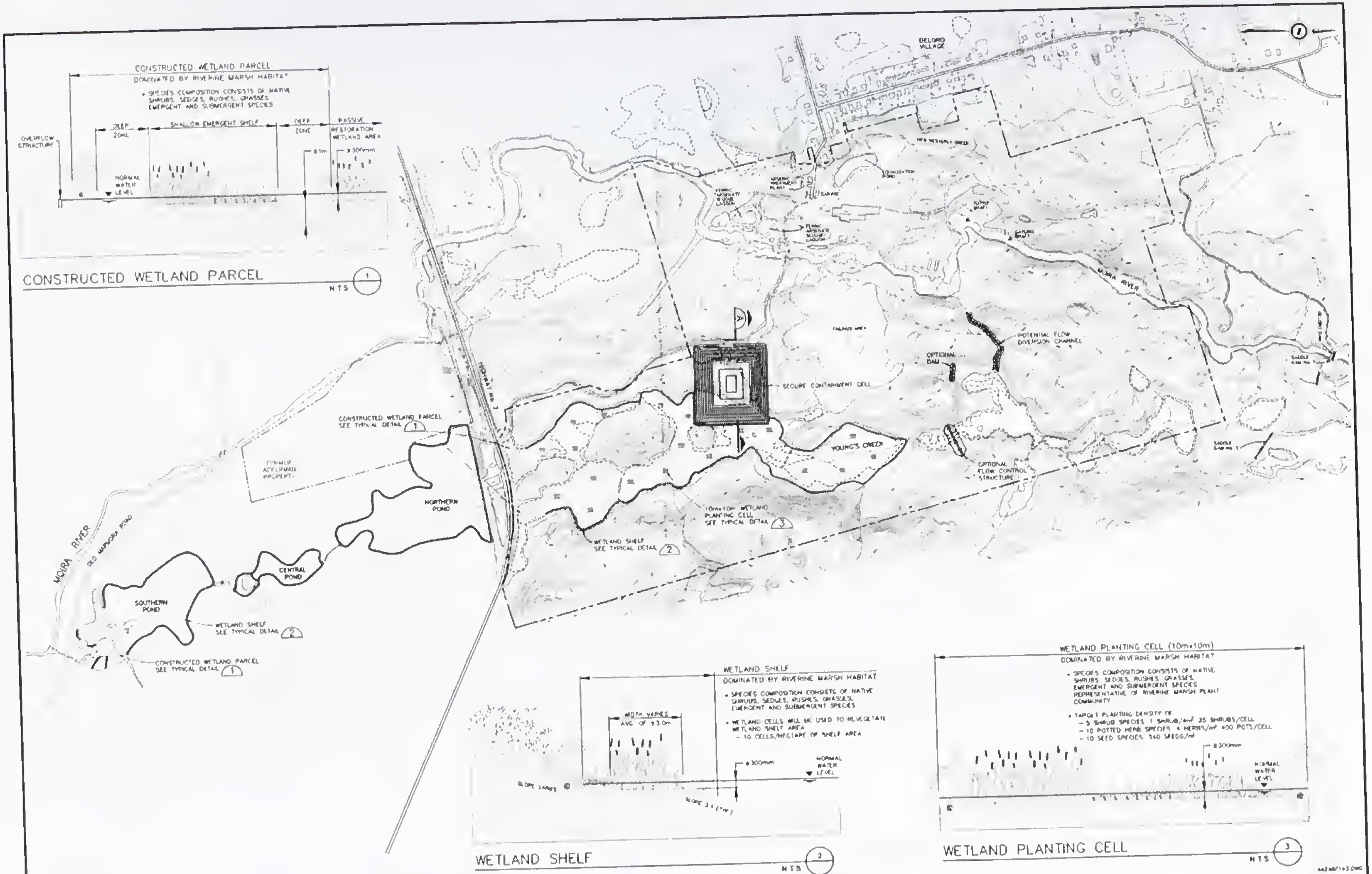
The third option for disposing of the excavated Young's Creek sediments is to place them in a separate secure disposal cell within the Young's Creek Area. Given the rugged topography of the site and the shallow bedrock, there is no ideal location for a secure disposal cell. A potential location for this containment cell is shown in Figure 5-1. The capacity of the storage cell shown in Figures 5-1 and 5-2 is approximately 260,000 m^3. This would be sufficient to accommodate the estimated volume of the most highly contaminated sediments (i.e. 160,000 m^3) from both onsite and offsite portions of the Young's Creek Area. The unused capacity could be used to store contaminated materials from other areas at the site if required. If the excess capacity was not required, the footprint of the storage cell could be reduced accordingly.

A secure landfill cell in the Young's Creek Area provides the most technically reliable disposal option. It also offers the additional benefit of being the closest disposal area for excavated sediments. In addition, it does not require transportation offsite nor does it create construction traffic in the Village of Deloro, which was identified as a concern by Village residents. Therefore, the most suitable onsite location for a secure containment cell to dispose of contaminated sediments would be within the Young's Creek Area.

Design features for the secure containment cell, as well as other remediation methods, need to consider the geochemical characteristics of the sediments in order to prevent contaminant mobility over the long term. In their current form, the sediments release contaminants to water but at a much lower level than might otherwise be expected given the high concentrations present in the sediment. This is believed to be attributable to the oxidizing environment that exists under current conditions. However, a potential exists for increased contaminant release under reducing conditions, particularly due to the presence of an organic substrate in the sediments. Methods for controlling the release of dissolved contaminants have a common theme: either a natural or an engineered repository that eliminates/minimizes water movement through the contaminated sediments. The successful method may involve either a wet or dry repository where the stored materials are maintained at a moisture content below the field capacity as a sound approach to mitigate the impacts of reducing conditions should they arise.

This method has the potential to mitigate any unacceptable impacts on human health or the environment in the long term, once natural sedimentation has taken place and the natural ecology of the Young's Creek Area has been re-established. However, there are some concerns in the short-term since the silty clay soil (underlying the contaminated sediments) that will be exposed following excavation has metal concentrations that exceed the Severe Effect Level (SEL) stated in the *Provincial Sediment Quality Guidelines* (PSQG) (MOE 1993). The SSRA, which will be completed for the entire site following selection of the preferred alternative, will assess the risk associated with exposed silty clay soils and determine whether additional measures (i.e. capping) will be required.

With respect to conformance of this method with government regulations, relying on natural sedimentation and natural processes to rehabilitate the area may not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek Area has been designated as a Class 2 provincially significant wetland (Snider, 2001). During a recent evaluation of the wetland area within the Young's Creek Area (Snider, 2001), it was recommended that "a simple wetland restoration plan" be prepared and implemented once the contaminated sediments have been remediated. Therefore, it can be expected that further rehabilitation efforts to re-establish the natural ecology will be required following the excavation of contaminated sediments.



DELORO VILLAGE
NEW METALLURGY SHED
EQUALIZATION POND
ARSENIC TREATMENT PLANT
GARAGE
FERRIC ARSENATE SLUDGE LAGOON
TAILINGS AREA
MOIRA RIVER
POTENTIAL FLOW DIVERSION CHANNEL
OPTIONAL DAM
SECURE CONTAINMENT CELL
A
C
YOUNG'S CREEK
OPTIONAL FLOW CONTROL STRUCTURE
SADDLE DAM No. 1
SADDLE DAM No. 2
HIGHWAY No. 7
10m×10m WETLAND PLANTING CELL SEE TYPICAL DETAIL 3
WETLAND SHELF SEE TYPICAL DETAIL 2
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
FORMER ACKERMAN PROPERTY
NORTHERN POND
CENTRAL POND
SOUTHERN POND
MOIRA RIVER
OLD MARMORA ROAD
CONSTRUCTED WETLAND PARCEL
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES EMERGENT AND SUBMERGENT SPECIES
OVERFLOW STRUCTURE
DEEP ZONE
SHALLOW EMERGENT SHELF
DEEP ZONE
PASSIVE RESTORATION WETLAND AREA
±1m
±300mm
NORMAL WATER LEVEL
CONSTRUCTED WETLAND PARCEL
NTS
1
WETLAND SHELF
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES
• WETLAND CELLS WILL BE USED TO REVEGETATE WETLAND SHELF AREA
– 10 CELLS/HECTARE OF SHELF AREA
WIDTH VARIES AVG. OF ±3.0m
±300mm
NORMAL WATER LEVEL
SLOPE VARIES
SLOPE 3:1 (TYP.)
WETLAND SHELF
NTS
2
WETLAND PLANTING CELL (10m×10m)
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES REPRESENTATIVE OF RIVERINE MARSH PLANT COMMUNITY
• TARGET PLANTING DENSITY OF
– 5 SHRUB SPECIES, 1 SHRUB/4m², 25 SHRUBS/CELL
– 10 POTTED HERB SPECIES, 4 HERBS/m², 400 POTS/CELL
– 10 SEED SPECIES, 340 SEEDS/m²
±300mm
NORMAL WATER LEVEL
WETLAND PLANTING CELL
NTS
3

LEGEND

PROPERTY LINE

0 200 400m

SCALE

NOTE
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPH BY NORTHWAY MAP TECHNOLOGY LIMITED (MAY 6, 1992)

NOTES

DFEYS

Ministry of the Environment
Ontario

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-1 YOUNG'S CREEK AREA PLAN VIEW OF CONCEPTUAL REMEDIATION METHODS

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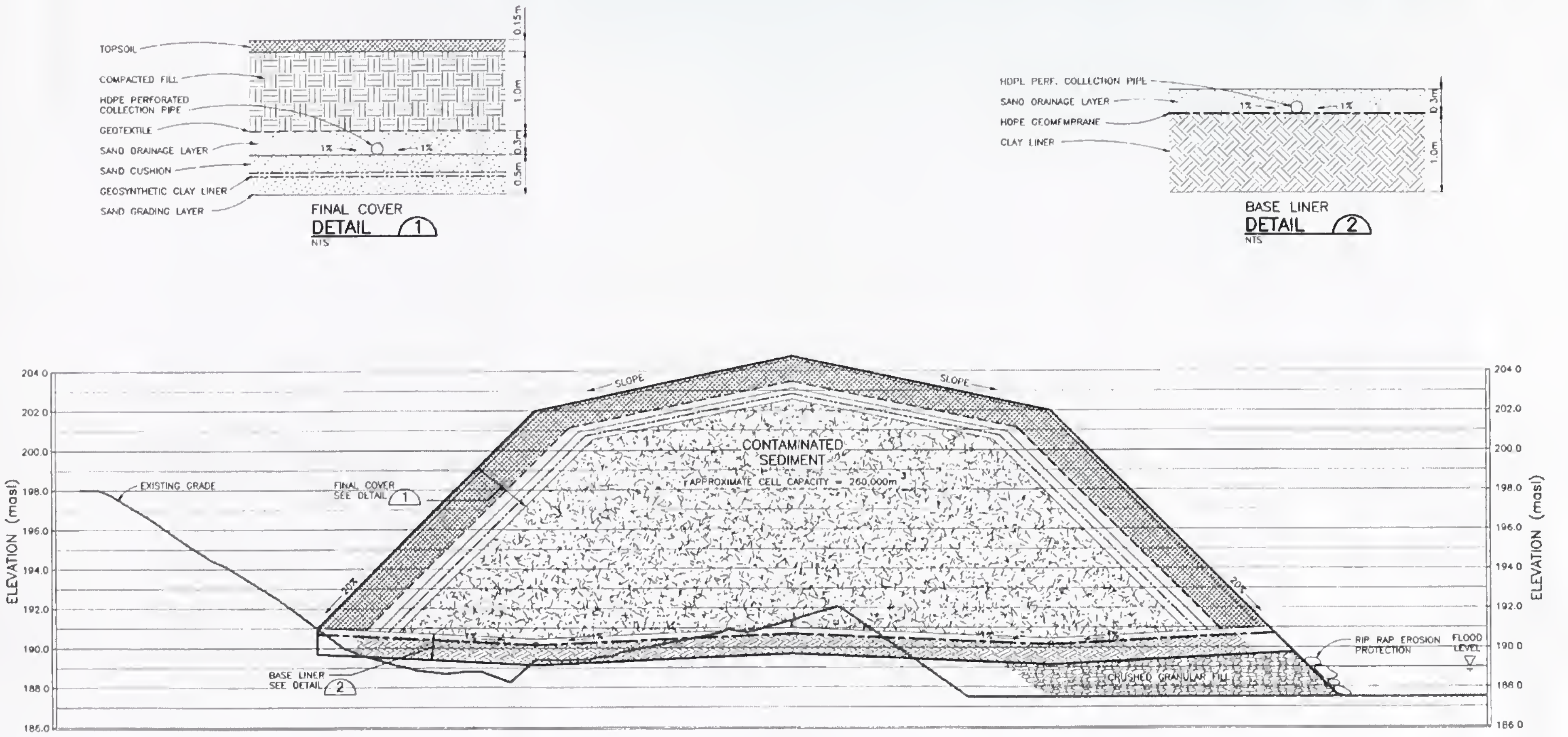

CH2MHILL

PROJECT No. 119548

REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-2 CONCEPTUAL DESIGN FOR YOUNG'S CREEK AREA SECURE CONTAINMENT CELL CROSS SECTION A-A' AND DETAILS

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This method has the potential to satisfy the design closure criteria and meet the remediation targets stated in Section 4. The onsite disposal cell can be designed to satisfy the physical, chemical, and radiological aspects of the design closure criteria.

5.2.2 Shallow Excavation (of Highly Contaminated Sediments) and Onsite Treatment

This method consists of excavating the uppermost highly contaminated organic and red mud sediments and treating them onsite using a soil washing type process. For the onsite portion of Young's Creek, these sediments primarily exist within the upper 0.5 m. The estimated volume of these highly contaminated sediments in the onsite portion of the Young's Creek Area is 100,000 m^3. For the offsite portion of Young's Creek, these sediments exist, on average, in the upper 0.3 m. However, at some locations, contaminated sediment is found as deep as 2 m. The estimated volume of these contaminated sediments in the offsite portion of the Young's Creek Area is 60,000 m^3, resulting in a total volume of 160,000 m^3.

If this method was considered alone, with no further action or enhancements, it would rely on natural sedimentation of non-contaminated sediments to replace the excavated material and cover the marginal contamination left behind and it would rely on natural processes to re-establish the natural ecology of the Young's Creek Area.

The treatment process consists of a relatively new soil remediation process known as the Pentaflux process, which has only been used at the pilot scale level.

With respect to the effectiveness of this method, the same comments can be made as were made for the Shallow Excavation and Disposal Onsite method. However, due to the treatment component of this method, there are serious concerns with respect to the ability of the process to treat the soil types, contaminant types and levels of contamination present at this site. In addition, this process creates hazardous sediment with concentrated metals that must be managed. Use of the technology beyond the pilot scale is very limited. Based on pilot scale costs provided by the vendor of this technology, this alternative is very cost prohibitive. This alternative does not offer any benefits over the Shallow Excavation and Disposal Onsite method and therefore does not have any potential as an enhancement feature.

5.2.3 Deep Excavation (of Highly Contaminated Sediments and Underlying Contaminated Silty Clay Soil) and Disposal Onsite

This method consists of excavating the uppermost highly contaminated organic and red mud sediments as well as the lesser contaminated underlying silty clay soil and disposing of these sediments in a secure onsite storage cell. While this option presents a greater risk of release of contaminants to the environment during implementation (e.g., through release of suspended solids), complete removal will be most effective in the long term, of all of the options considered. Therefore, this method is effective and will potentially meet government policies and regulations, as well as design criteria.

If this method was considered alone, with no further action or enhancements, it would rely on natural sedimentation of non-contaminated sediments to replace the excavated material and on natural processes to re-establish the natural ecology of the Young's Creek Area.

The volumes of contaminated sediments and underlying contaminated silty clay soil within the Young's Creek Area, their location (onsite or offsite), their depth, average and highest arsenic concentrations, and soil type are summarized in Table 5.1.

The total volume of contaminated sediments and underlying soils in the onsite and offsite portion of the Young's Creek Area is on the order of 329,000 m^3. With respect to onsite disposal options, three locations have been identified. These include the Industrial Area, the Tailings Area, and within the Young's Creek Area itself. As discussed under the shallow excavation alternative, the Industrial Area lacked sufficient capacity to accommodate even the most highly contaminated sediments and, therefore, was dismissed as a viable option.

The Tailings Area was also dismissed as a viable disposal location for the highly contaminated sediments. Placing these sediments under a soil cover on the Tailings Area may lower the redox potential in the pore water, and in doing so could liberate additional arsenic into solution (SRK, 1998). However, the lesser contaminated underlying sediments could possibly be used as a capping material for the Tailings Area. A potential alternative for the Tailings Area is a soil cover and re-vegetation using poplar tree technology. Placing the less contaminated deeper silty clay soils on the Tailings Area will reduce the costs of transporting soil from offsite to cap the Tailings Area. However, prior to implementation, the structural stability of the tailings dams must be tested and additional reinforcement of the dams must be provided, if necessary. The applicability of using the silty clay soils with the poplar tree technology must also be confirmed from a phytotoxicity perspective.

As discussed previously, the preferred location for a secure containment cell to dispose of the highly contaminated upper sediments is within the Young's Creek Area. A potential location for this containment cell is shown in Figure 5-1. The capacity of the storage cell shown in Figure 5-1 is approximately 260,000 m^3. This storage cell would be sufficient to accommodate the estimated volume of the most highly contaminated sediments (i.e. 160,000 m^3) from both the onsite and offsite portions of the Young's Creek Area as well as the lesser contaminated underlying silty clay soil from onsite (99,000 m^3). Expanding the storage cell footprint in the Young's Creek Area to accommodate all of the contaminated sediments (329,000 m^3) is possible but would result in further encroachment onto and alteration of the existing floodplain. If feasible, it would be preferable to use as much of the lesser contaminated underlying silty clay soil as possible for use as cover material for the Tailings Area.

This method has the potential to mitigate any unacceptable impacts on human health or the environment in the long term since all contaminated sediments would be removed. There may be a concern with this method since relying on natural sedimentation and natural processes to rehabilitate the area may not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek Area has been designated as a Class 2 provincially significant wetland (Snider, 2001). During a recent evaluation of the wetland area within the Young's Creek Area (Snider, 2001), it was recommended that "a simple wetland restoration plan" be prepared and implemented once the contaminated sediments have been remediated. Therefore, it can be expected that some form of rehabilitation effort to re-establish the natural ecology will be required.

5.2.4 In-Place Capping of Contaminated Sediments

This method involves covering the entire Young's Creek Area downstream of the east tailings dam to the Moira River with a layer of sandy fill to reduce surface exposure to radiation hazard and metal contamination and reduce contamination of surface water due to erosion and suspension of contaminated particles.

The cover would also lower dissolved metal concentrations in the surface water, but this reduction would likely be short-lived. With time, dissolved metal concentrations in pore water of the cover material may rise due to diffusion from the underlying contaminated soils, and the rate of loading for dissolved constituents may eventually rise.

Another potential problem is that the cover material may not remain intact, due to the lack of geotechnical strength and high moisture content of the underlying sediments. The placed cap materials may erode during flood events exposing the underlying contaminated sediment. Capping the contaminated sediments alone, also does not mitigate the risk to burrowing animals or deep rooted vegetation.

With respect to conformance to government regulations and guidelines, there may be a concern since relying on natural sedimentation and natural processes to rehabilitate the area may not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek Area has been designated as a Class 2 provincially significant wetland (Snider, 2001). During a recent evaluation of the wetland area within the Young's Creek Area (Snider, 2001), it was recommended that "a simple wetland restoration plan" be prepared and implemented once the contaminated sediments have been remediated. Therefore, it can be expected that some form of rehabilitation effort to re-establish the natural ecology will be required.

Although this method will have short-term benefits, its effectiveness over the long term is unlikely to meet the objectives. Consequently, it does not meet the effectiveness criterion, conformance to government regulations or the design closure criterion. However, this method does have the potential to enhance some of the other long listed remediation methods and will be considered during the development of the Comprehensive Remediation Alternatives.

5.2.5 Creek Rehabilitation

This method consists of engineered creek rehabilitation efforts such as planting of native species by seed or transplant, grading, and fill placement to create hydrologic conditions that are conducive to re-establishing Young's Creek as a Class 2 wetland. This method obviously is not a stand-alone method, since contaminated sediment removal will be essential prior to implementation. As described previously under the remediation methods involving excavation of contaminated materials, the following two excavation depths are being considered:

- Shallow Excavation (approximately 500 mm excavation depth) of the most highly contaminated sediments combined with an option to cap underlying sediments with 300 mm of new uncontaminated soil

- Deep Excavation (approximately 1500 mm excavation depth) of both highly contaminated sediments and underlying lesser contaminated silty clay soils with metal concentrations above the SEL concentrations.

Regardless of the excavation depth, the deepening of the Young's Creek drainage corridor will impact its topographical profile, hydrological conditions, soil conditions, and the plant communities associated with them.

Hydrology is the critical element when establishing wetland environments. Shallow excavation will result in an overall increase in water depth of about 200 mm in the onsite portion of the creek basin. The slight decrease in elevation will have limited impact on the general environmental context of the creek corridor. Successful restoration efforts should result in the creation of diverse wetland communities consistent with the existing dominant riverine marsh habitat. The deep excavation option, however, will result in significantly deeper water depths within the creek corridor. It is expected that a majority of the creek corridor will be dominated by a pond/shallow water body setting with water depths up to 1500 mm. Opportunities for the restoration of the dominant riverine marsh habitat will be limited to areas with the appropriate hydrological conditions.

The restoration methods under both excavation depths being considered will involve both passive and active establishment of target plant communities associated with specific wetland environments. The majority of the site will be allowed to re-vegetate naturally from the local seed bed from adjacent and upstream communities. If the proper hydrologic conditions are established, this is a very successful way of re-introducing native plant communities within large tracks of land. Seed material and potted plant stock should be utilized to speed up the restoration process in target areas and provide a localized seed bed for future colonization of the passive restoration area. The quick establishment of a wetland environment may also be required to control erosion, provide treatment (filtering, extraction of contaminants by plants) and for aesthetic purposes. Specific details of the efforts needed to establish this wetland environment are provided separately below for each of the excavation depths being considered.

Creek Rehabilitation Measures for the Shallow Excavation Option

Shallow excavation will involve the removal of the uppermost highly contaminated soil. If the capping option is selected, 300 mm of imported soil would result in a wetland environment that is relatively consistent with the current conditions. The imported soil should be physically and chemically consistent with the existing silty clay surface soil. Of the 300 mm depth, the top 75-100 mm should consist of a loam topsoil to provide an ideal environment for plant germination and root development. The imported soil depth also acts as a physical barrier from the contaminated subsurface soils. The 300 mm soil depth will reduce direct contact of water, plant material and animals with the contaminated subsurface. Partial excavation in the offsite portion of the Young's Creek Area will not significantly alter the hydrologic or current wetland conditions south of Highway 7.

The majority of the remediated area would be restored allowing the local seed bed to regenerate the wetland plant community naturally. It is expected that if appropriate hydrological conditions are established that are relatively consistent with the existing wetlands, it will provide an ideal environment for the utilization of this restoration method.

In addition, more intensive planting using local seed material and potted plant stock is suggested at select locations within the creek corridor. Water quality improvements associated with wetlands would be the primary benefit derived from quick wetland establishment. Priority should be given to the establishment of a wetland parcel at the southern extent of the remediated area just upstream of Highway 7 as shown in Figure 5-1. A similar wetland parcel would be established at the lower end of the Southern Pond prior to the point of discharge at the Moira River. The wetland would provide some level of treatment and filtration prior to the discharge of creek water into the Southern Pond and the Moira River.

It is also recommended that a series of wetland planting cells be initiated at strategic locations throughout the remediated area as shown in Figure 5-1. The wetland planting cell is a 10 m by 10 m area within which a specific plant mix is established that consists of seed, and potted plant stock. The wetland planting cells replace the seed bed contained in the upper 500 mm of stripped soil and the substrate seed bed that was covered with 300 mm of imported soil.

Creek Rehabilitation Measures for the Deep Excavation Option

Deep excavation will involve the removal of approximately 1500 mm of contaminated soil and would result in a wetland environment that is significantly different from the current conditions, in the onsite portion of the creek basin. Full excavation in the offsite portion of the Young's Creek Area will not significantly alter the wetland environment south of Highway 7. The majority of the remediated area would consist of wet areas that are in excess of 1500 mm in depth. Wetland environments would be restricted to the littoral zones surrounding the perimeter of the ponds. Grading could be carried out to provide a wetland shelf around the perimeter of the wet areas, as shown in Figure 5-1, to increase the wetland component. The shelf would be graded to provide an optimum water depth to support a diverse wetland community associated with the dominant riverine marsh habitat. The shelf would be continuous around the perimeter and have varying widths based on an aesthetic requirement. A 75-100 mm depth of topsoil would be required on top of the wetland shelf to provide an ideal environment for seed germination and subsequent root development. The shelf would provide limited treatment potential but instead would stabilize the soil and provide an aesthetic function.

Again, the majority of the remediated area would be restored allowing the local seed bed to regenerate the wetland plant community. The wetland restoration area, however, would be considerably smaller in size, compared to the shallow excavation option, given the extent of the predicted wet area. The hydrological condition that was established within the wetland shelf around the perimeter of the wet areas would provide an ideal environment for the natural re-vegetation to occur. In an effort to provide some water quality improvements, priority should once again be given to the establishment of two wetland parcels as shown in Figure 5-1. One parcel would be located at the southern extent of remediated area just upstream of Highway 7 and the other parcel would be located just upstream of the point of discharge into the Moira River. The wetlands would provide some level of treatment and filtration prior to the discharge of creek water into the Southern Pond and the Moira River. It is also recommended that a series of wetland planting cells be initiated at strategic locations within the wetland shelf similar to those described for the shallow excavation option.

It is important to note that the natural environment within the Young's Creek corridor is a dynamic one that is greatly influenced by the local beaver population. The beaver dams have a significant impact on the hydrological context of the creek corridor. The natural regeneration of the site fits well into such a dynamic site. Plants are opportunistic organisms that react to the environmental context in which they grow. If you provide the ideal environment for a specific plant community, natural regeneration will occur over time assuming there is an appropriate seed bed available. Other specific design elements that will need to be established after remediation activities have been carried out include:

- Stream channel design
- Bioengineering of banks
- Sediment control and management
- Water elevation control options
- Plant species selection based on target plant communities

This method addresses concerns with respect to satisfying anticipated MNR requirements for restoration of the contaminated portion of the Young's Creek Area. Again, this method is obviously not a stand-alone method since planting efforts under existing sediment conditions would be unsuccessful. However, creek rehabilitation is recommended and should be an integral component of the comprehensive remediation alternative for the Young's Creek Area.

5.2.6 Flow Diversion Away from Most Highly Contaminated Sediments

The flow from the upper portions of Young's Creek currently passes through both the east and west sides of the Young's Creek Area, depending on the flow rates and the heights and locations of the beaver dams within the Young's Creek Area. The investigations indicate that the most radioactive and most arsenic and metal-contaminated sediments are adjacent to the east dam of the Tailings Area.

Diverting all the flow through the east half of the Young's Creek Area would greatly reduce the amount of surface water coming in contact with the most contaminated sediments. Excavating the contaminated material from the east side and moving it to the west side would further reduce or eliminate surface water contact with contaminated sediments. The west side could then be covered to provide reduced risks of exposure to radiation and arsenic and metal contamination. The diversion could be accomplished by constructing divider dykes between the islands separating the east and west halves of the Young's Creek Area.

The effectiveness of this method may be short-lived. The cover material on the west side may be eroded due to the lack of geotechnical strength of the sediments, their high moisture content and occasional flooding. In addition, diverting flow and construction of divider dykes across the Young's Creek Area may negatively impact the existing ecosystems, as well as increase flooding near Highway 7. These impacts would likely be inconsistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority.

5.2.7 Flow Regulation in the Contaminated Portion of the Young's Creek Area

This method consists of constructing a flow control structure (i.e. dam) upstream of the Tailings Area at the proposed location shown in Figure 5-1. The purpose of the dam would be to regulate the flow moving through the contaminated portion of the Young's Creek Area. Flow regulation through the contaminated portion of the creek would act to mitigate the concern that during a flood event a large quantity of contaminated sediments within the Young's Creek Area would become suspended and be transported to the Moira River. This could result in a significant metal loading to the Moira River during the flood event.

During a flood event, excess flow from the portion of Young's Creek upstream of the contaminated sediments, would be diverted to the Moira River through an excavated/blasted channel as shown in Figure 5-1 (i.e. potential flow diversion channel). A dam structure (i.e. optional dam) would also need to be constructed to prevent the flow from entering the Tailings Area. For this method, the effects of diverting additional flow to the Moira River during flood events would need to be confirmed from a floodplain mapping perspective.

With respect to effectiveness, this alternative does not mitigate unacceptable impacts to human health or the environment. This alternative simply ensures that a one-time contaminant loading to the Moira River will be less likely to occur during a flood event. Therefore this alternative will not be considered as a primary remediation method, but may be considered as an enhancement to another alternative. For example, the shallow excavation option combined with in-place capping would be enhanced if the flow during a flood event was regulated. This would reduce the possibility of erosion of placed cap material and exposure of the lesser contaminated underlying silty clay soils. This alternative may also facilitate the implementation of sediment excavation, since flow could be diverted temporarily during the excavation of contaminated sediment and soil.

5.3 Screening of Conceptual Remediation Methods

5.3.1 Screening of Long List of Conceptual Remediation Methods

The second step used in the generation of remedial methods was to compare the conceptual remediation methods listed above to the set of exclusionary criteria identified in Table 4.1. As explained in Section 4.3, these criteria were designed to screen out, early in the process, improbable conceptual remediation methods for the area under consideration. Table 5.2 summarizes the evaluation of the seven conceptual remediation methods against the exclusionary criteria. The "Do Nothing" alternative has been included in Table 5.2 as a benchmark comparison point, as noted in Section 5.2.

In Section 4, a primary remediation method is defined as a method that has significant potential to address most of the environmental issues in this area of the site without further augmentation or enhancement. Two of the remediation methods can be considered primary remediation methods. These include:

- Shallow Excavation and Disposal Onsite
- Deep Excavation and Disposal Onsite

Of the remaining 5 remediation methods, 3 methods were identified that could be used to augment or enhance the primary remediation methods. These include:

- In-Place Capping
- Creek Rehabilitation
- Flow Regulation

The remaining two remediation methods that were screened from any further consideration include:

- Shallow Excavation and Onsite Treatment
- Flow Diversion

5.3.2 Development of Comprehensive Remediation Alternatives

The next step in generating the remediation alternatives consisted of combining the two primary remediation methods with the three enhancing environmental protection features, where appropriate, to produce comprehensive remediation alternatives. The resulting comprehensive remediation alternatives include:

A. Shallow Excavation Alternatives

- Shallow Excavation, Disposal Onsite, In-Place Capping
- Shallow Excavation, Disposal Onsite, Creek Rehabilitation
- Shallow Excavation, Disposal Onsite, In-Place Capping, Flow Regulation
- Shallow Excavation, Disposal Onsite, In-Place Capping, Creek Rehabilitation
- Shallow Excavation, Disposal Onsite, In-Place Capping, Flow Regulation, Creek Rehabilitation

B. Deep Excavation Alternatives

- Deep Excavation, Disposal Onsite
- Deep Excavation, Disposal Onsite, Creek Rehabilitation

For the shallow excavation alternatives, highly contaminated sediments would be disposed of in a secure containment cell within the Young's Creek Area. For the deep excavation alternatives, highly contaminated sediments and the most contaminated underlying silty clay soils would be disposed of in a secure containment cell within the Young's Creek Area. The remaining underlying lesser contaminated silty clay soils could potentially be used under the soil cover in the Tailings Area.

5.3.3 Screening of Comprehensive Remediation Alternatives

The comprehensive remediation alternatives listed above were evaluated a second time against the exclusionary criteria because they resulted from a combination of primary remediation methods and enhancing environmental protection features. This second evaluation was performed to determine if the combination of methods (used to develop the comprehensive remediation alternatives) could satisfy the exclusionary criteria in terms of an overall reduction in contaminant load from the Young's Creek Area.

TABLE 5.2 (SEE FIGURE 4-1)
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Do Nothing	Does not meet project objective	Arsenic and other contaminant loads will be unacceptable or could increase with sediment erosion.	Method has no potential to satisfy design closure criteria.	No	No
Shallow Excavation and Disposal Onsite	Has the potential to mitigate any unacceptable impacts on human health or the environment in the long term, once natural sedimentation has taken place and the natural ecology of the basin has been re-established. The effectiveness in the short-term is more questionable however since the soil (underlying the excavated sediments) will remain that has metals concentrations above the SEL Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation.	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR and Conservation Authority concurrence. Short term concerns exist since sediments will be left behind under this alternative that exceed the SEL . Relying on natural sedimentation and natural processes to rehabilitate the area may not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek basin has been designated as a Class 2 provincially significant wetland (Snider, 2001). Creek rehabilitation may be an MNR requirement.	Method has potential to satisfy the design closure criteria. The design of the containment cell must satisfy the design closure criteria.	Yes	No
Shallow Excavation and Onsite Treatment	Same comments as for the Shallow Excavation and Disposal Onsite method. In addition, there are concerns with respect to the ability of the onsite treatment component of this method. The treatment process does not have a proven track record beyond the pilot scale and is cost prohibitive at the current stage of development.	Short term concerns since sediments will be left behind under this alternative that exceed the Severe Effect Level stated in the MOE Guidelines. Relying on natural sedimentation and natural processes to rehabilitate the area may not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek basin has been designated as a Class 2 provincially significant wetland (Snider, 2001). Creek rehabilitation may be an MNR requirement.	Method has potential to satisfy the design closure criteria. The design of the containment cell must satisfy the design closure criteria.	No	No

TABLE 5.2 (SEE FIGURE 4-1)
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Deep Excavation and Disposal Onsite	Has the potential to mitigate any unacceptable impacts on human health or the environment in the long term since all contaminated sediments would be removed. Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation.	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence. The Young's Creek Basin has been designated as a Class 2 provincially significant wetland (Snider, 2001). Creek rehabilitation may be an MNR requirement.	Method has potential to satisfy the design closure criteria. The design of the containment cell must satisfy the design closure criteria.	Yes	Yes
In-Place Capping of Contaminated Sediments	Short term reduction in dissolved metal concentrations in surface water; however, long term dissolved metal concentrations in pore water of the cover material may rise due to diffusion from the underlying contaminated soils, and the rate of loading for dissolved constituents may eventually rise. Cover material may not remain intact, due to the lack of geotechnical strength of the underlying sediments, its high moisture content, and its occasional flooding, as well as the effect of erosive forces.	Short term concerns exist since highly contaminated sediments will be left behind under this alternative that exceed the SEL. Relying on natural sedimentation and natural processes to rehabilitate the area may not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek basin has been designated as a Class 2 provincially significant wetland (Snider, 2001). Creek rehabilitation may be an MNR requirement.	Method does not have the potential to satisfy design closure criteria. Given the site conditions, it is practically impossible to design a cap system that can meet the physical (ie. 100-year storm flow), chemical, or radiological aspects.	No	Yes
Creek Rehabilitation	This alternative alone does not have the ability to reduce contaminant load. Creek rehabilitation efforts will be futile given the current level of contamination in the creek sediment.	Short term concerns since sediments will be left behind under this alternative that exceed the SEL. Creek rehabilitation is likely to be an MNR and Conservation Authority requirement for the selected comprehensive remediation alternative.	Method does not have the potential to satisfy design closure criteria given the current site conditions.	No	Yes

TABLE 5.2 (SEE FIGURE 4-1)
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as Primary?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Flow Diversion	Cover material on the west side of the channel may not remain intact, due to the lack of geotechnical strength of the underlying sediments, its high moisture content, and its occasional flooding, as well as the effect of erosive forces. Does not address Offsite contamination.	May negatively impact the existing ecosystems, as well as increase flooding near Highway 7. These impacts would likely be inconsistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority.	Method does not have the potential to satisfy design closure criteria given the current site conditions.	No	No
Flow Regulation	Prevents a one-time high contaminant loading to the Moira River during a flood event. Does not reduce contaminant load or solve the problem.	Method will be unacceptable to the MNR and Conservation Authority since there is no restoration of the damaged wetland. Method will be unacceptable to the MOE due to the high levels of contamination that will remain both onsite and offsite.	Method does not have the ability to satisfy design closure criteria.	No	Yes

A summary of whether the comprehensive remediation alternatives did or did not satisfy these criteria for both the onsite and offsite portions of Young's Creek is presented in Table 5.3. The comprehensive alternatives were assessed against evaluation criteria separately for the onsite and offsite portions of Young's Creek in order to consider the significant differences between the two. For example, the offsite portion is privately owned, has considerably lower contaminant concentrations in the sediments and underlying soils, and consists primarily of deeper ponded areas.

5.3.4 Short List of Comprehensive Remediation Alternatives

The following comprehensive remediation alternatives satisfied the second set of exclusionary criteria to form the short list of remedial alternatives. The short list of comprehensive remediation alternatives are listed below:

- Shallow Excavation, Disposal Onsite, Creek Rehabilitation (offsite portion only)
- Shallow Excavation, Disposal Onsite, In-Place Capping, Creek Rehabilitation
- Shallow Excavation, Disposal Onsite, In-Place Capping, Flow Regulation, Creek Rehabilitation
- Deep Excavation, Disposal Onsite, Creek Rehabilitation

It is noted that all of the comprehensive remediation alternatives include an excavation component, onsite disposal, and creek rehabilitation. For the shallow excavation alternatives, in-place capping and flow regulation could be considered to be enhancements. Therefore the four comprehensive alternatives listed above could be simplified to two comprehensive remediation alternatives as follows:

1. Shallow Excavation, Disposal Onsite, Creek Rehabilitation with enhancing features:
   - In-Place Capping (mandatory for the onsite portion)
   - Flow Regulation

2. Deep Excavation, Disposal Onsite, Creek Rehabilitation

These comprehensive remediation alternatives can be formed into a variety of combinations, if one assumes that different comprehensive alternatives could be used for the onsite and offsite portions of Young's Creek. For example, the shallow excavation alternative could be used offsite, while the deep excavation alternative could be used onsite. In theory, four combinations can be formed as follows. For the sake of brevity, short-forms for the lengthy titles used above for the two main comprehensive remediation alternatives have been used below. For example, the term shallow excavation below also includes the onsite disposal, creek rehabilitation and the enhancement features.

	Onsite	**Offsite**
Scenario 1	Shallow Excavation	Shallow Excavation
Scenario 2	Deep Excavation	Shallow Excavation
Scenario 3	Shallow Excavation	Deep Excavation
Scenario 4	Deep Excavation	Deep Excavation

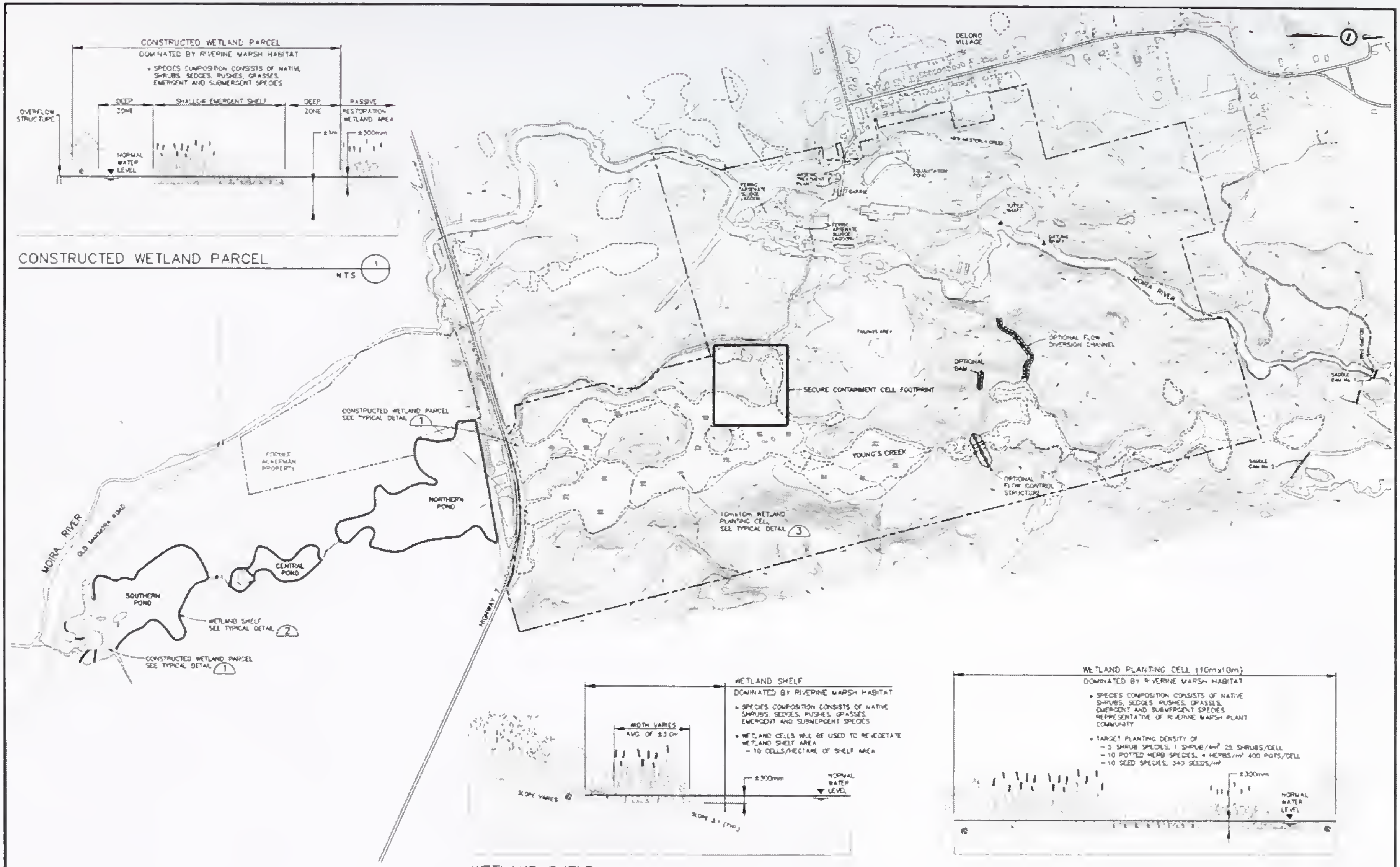
Conceptual details associated with each of these four possible scenarios are shown in Figures 5-3, 5-4, 5-5 and 5-6.

TABLE 5.3
SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Comprehensive Remediation Alternative	Exclusionary Criteria			
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria	Meets Exclusionary Criteria? Onsite/Offsite
Shallow Excavation, Disposal Onsite, In-Place Capping	Effective in the short term. Long term effectiveness relies on the ability of the cap materials to remain in-place and isolate the underlying contaminated sediments, particularly in the onsite portion of Young's Creek Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation. Control measures can be used to mitigate these risks.	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence. Soil will be left behind under this alternative that exceed the SEL. Relying on the placed cap materials to isolate the silty clay soil with metals concentrations above the SEL may not be acceptable to the MOE unless an ecological risk assessment is completed that confirms this alternative mitigates unacceptable impacts to human health or the environment. Relying on natural processes to rehabilitate the area will not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek basin has been designated as a Class 2 provincially significant wetland (Snider, 2001). Creek rehabilitation may be an MNR requirement.	The design of the containment cell must satisfy the design closure criteria. There are concerns with designing a cap that can satisfy the design closure criteria	No / No
Shallow Excavation, Disposal Onsite, Creek Rehabilitation	Better suited to the offsite portion of Young's Creek where metal concentrations in the underlying soils approach Moira River and Moira Lake concentrations. Potential for unacceptable impacts on human health or the environment in the onsite portion of Young's Creek since the underlying soils contain metal concentrations well above the SEL. Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation. Control measures can be used to mitigate these risks	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence. Soil will be left behind under this alternative that exceed the SEL. Relying on natural sedimentation to isolate the silty clay soil with metals concentrations above the SEL may not be acceptable to the MOE unless an ecological risk assessment is completed that confirms this alternative mitigates unacceptable impacts to human health or the environment.	The design of the containment cell must satisfy the design closure criteria.	No / Yes
Shallow Excavation, Disposal Onsite, In-Place Capping, Flow Regulation	Effective in the short term. Long term effectiveness relies on the ability of the cap materials to remain in-place and isolate the underlying contaminated sediments, particularly in the onsite portion of Young's Creek. Flow regulation will minimize displacement of placed cap materials during flood events in the onsite portion of Young's Creek. For the offsite portion, flow regulation is already provided by the culvert at Highway 7. Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation. Control measures can be used to mitigate these risks	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence. Soil will be left behind under this alternative that exceed the SEL. Relying on the placed cap materials to isolate the silty clay soil with metals concentrations above the SEL may not be acceptable to the MOE unless an ecological risk assessment is completed that confirms this alternative mitigates unacceptable impacts to human health or the environment. Relying on natural processes to rehabilitate the area will not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority. The Young's Creek basin has been designated as a Class 2 provincially significant wetland (Snider, 2001). Creek rehabilitation may be an MNR requirement. Flow regulation measures will require MOE, MNR and Conservation Authority concurrence.	The design of the containment cell and flow regulation measures must satisfy the design closure criteria. There are concerns with designing a cap that can satisfy the design closure criteria	No / No
Shallow Excavation, Disposal Onsite, In-Place Capping, Creek Rehabilitation	Effective in the short term. Long term effectiveness relies on the ability of the cap materials to remain in-place and isolate the underlying contaminated sediments, particularly in the onsite portion of Young's Creek. Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation. Control measures can be used to mitigate these risks.	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence. Soil will be left behind under this alternative that exceed the SEL. Relying on the placed cap materials to isolate the silty clay soil with metals concentrations above the SEL may not be acceptable to the MOE unless an ecological risk assessment is completed that confirms this alternative mitigates unacceptable impacts to human health or the environment.	The design of the containment cell must satisfy the design closure criteria. There are concerns with designing a cap that can satisfy the design closure criteria	Yes / Yes

TABLE 5.3
SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Comprehensive Remediation Alternative	Exclusionary Criteria			
	Effectiveness	**Government Regulations and Guidelines**	**Design Closure Criteria**	**Meets Exclusionary Criteria?** **Onsite/Offsite**
Shallow Excavation, Disposal Onsite, In-Place Capping, Flow Regulation, Creek Rehabilitation	Effective in the short term. Long term effectiveness relies on the ability of the cap materials to remain in-place and isolate the underlying contaminated sediments, particularly in the onsite portion of Young's Creek. Flow regulation will minimize displacement of placed cap materials during flood events in the onsite portion of Young's Creek. For the offsite portion, flow regulation is already provided by the culvert at Highway 7. Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation. Control measures can be used to mitigate these risks.	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence. Flow regulation measures will require MOE, MNR and Conservation Authority concurrence. Soil will be left behind under this alternative that exceed the SEL. Relying on the placed cap materials to isolate the silty clay soil with metals concentrations above the SEL may not be acceptable to the MOE unless an ecological risk assessment is completed that confirms this alternative mitigates unacceptable impacts to human health or the environment.	The design of the containment cell and flow regulation measures must satisfy the design closure criteria There are concerns with designing a cap that can satisfy the design closure criteria.	Yes / Yes
Deep Excavation, Disposal Onsite	Will mitigate any unacceptable impacts on human health or the environment in the long term since all contaminated sediments would be removed Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation. Control measures can be used to mitigate these risks.	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence. Relying on natural processes to rehabilitate the area will not be consistent with the generally accepted policies and regulations of the MNR and/or the Conservation Authority The Youngs Creek basin has been designated as a Class 2 provincially significant wetland (Snider, 2001). Creek rehabilitation may be an MNR requirement.	The design of the containment cell must satisfy the design closure criteria	No / No
Deep Excavation, Disposal Onsite, Creek Rehabilitation	Will mitigate any unacceptable impacts on human health or the environment in the long term since all contaminated sediments would be removed. Exposure risk during implementation due to re-suspension of contaminated sediment during construction. Potential exposure risk to workers during implementation. Control measures can be used to mitigate these risks.	Locating secure containment cell in the Young's Creek Basin will require MOE, MNR, and Conservation Authority concurrence	The design of the containment cell must satisfy the design closure criteria	Yes / Yes


CONSTRUCTED WETLAND PARCEL
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES
OVERFLOW STRUCTURE
DEEP ZONE
SHALLOW EMERGENT SHELF
DEEP ZONE
PASSIVE RESTORATION WETLAND AREA
±1m
±300mm
NORMAL WATER LEVEL
DELORO VILLAGE
NEW MEYERS CREEK
EQUALIZATION POND
ARSENIC TREATMENT PLANT
GARAGE
FERRIC ARSENATE SLUDGE LAGOON
FERRIC ARSENATE SLUDGE LAGOON
SUPPLE SHAFT
GATLING SHAFT
MOIRA RIVER
TAILINGS AREA
OPTIONAL FLOW DIVERSION CHANNEL
OPTIONAL DAM
SECURE CONTAINMENT CELL FOOTPRINT
YOUNG'S CREEK
OPTIONAL FLOW CONTROL STRUCTURE
SADDLE DAM No. 1
SADDLE DAM No. 2
DELORO DAM
10m x 10m WETLAND PLANTING CELL SEE TYPICAL DETAIL 3
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
FORMER ACKERMAN PROPERTY
NORTHERN POND
CENTRAL POND
SOUTHERN POND
WETLAND SHELF SEE TYPICAL DETAIL 2
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
MOIRA RIVER
OLD MARMORA ROAD
HIGHWAY 7
WETLAND SHELF
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES
• WETLAND CELLS WILL BE USED TO REVEGETATE WETLAND SHELF AREA
– 10 CELLS/HECTARE OF SHELF AREA
WIDTH VARIES
AVG. OF ±30m
±300mm
NORMAL WATER LEVEL
SLOPE VARIES
SLOPE 5:1 (TYP.)
WETLAND PLANTING CELL (10m x 10m)
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES REPRESENTATIVE OF RIVERINE MARSH PLANT COMMUNITY
• TARGET PLANTING DENSITY OF
– 5 SHRUB SPECIES, 1 SHRUB/4m² 25 SHRUBS/CELL
– 10 POTTED HERB SPECIES, 4 HERBS/m² 400 POTS/CELL
– 10 SEED SPECIES, 340 SEEDS/m²
±300mm
NORMAL WATER LEVEL

CONSTRUCTED WETLAND PARCEL (1) NTS

WETLAND SHELF (2) NTS

WETLAND PLANTING CELL (3) NTS

LEGEND

PROPERTY LINE

0 200 400m
SCALE

NOTE
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPHY BY NORTHWAY MAP TECHNOLOGY LIMITED (MAY 6, 1992)

44246/T4.38 DWG

NOTES

1. [illegible]

2. [illegible]

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-3 YOUNG'S CREEK AREA PLAN VIEW OF COMPREHENSIVE REMEDIATION ALTERNATIVE
SHALLOW EXCAVATION ONSITE
SHALLOW EXCAVATION OFFSITE

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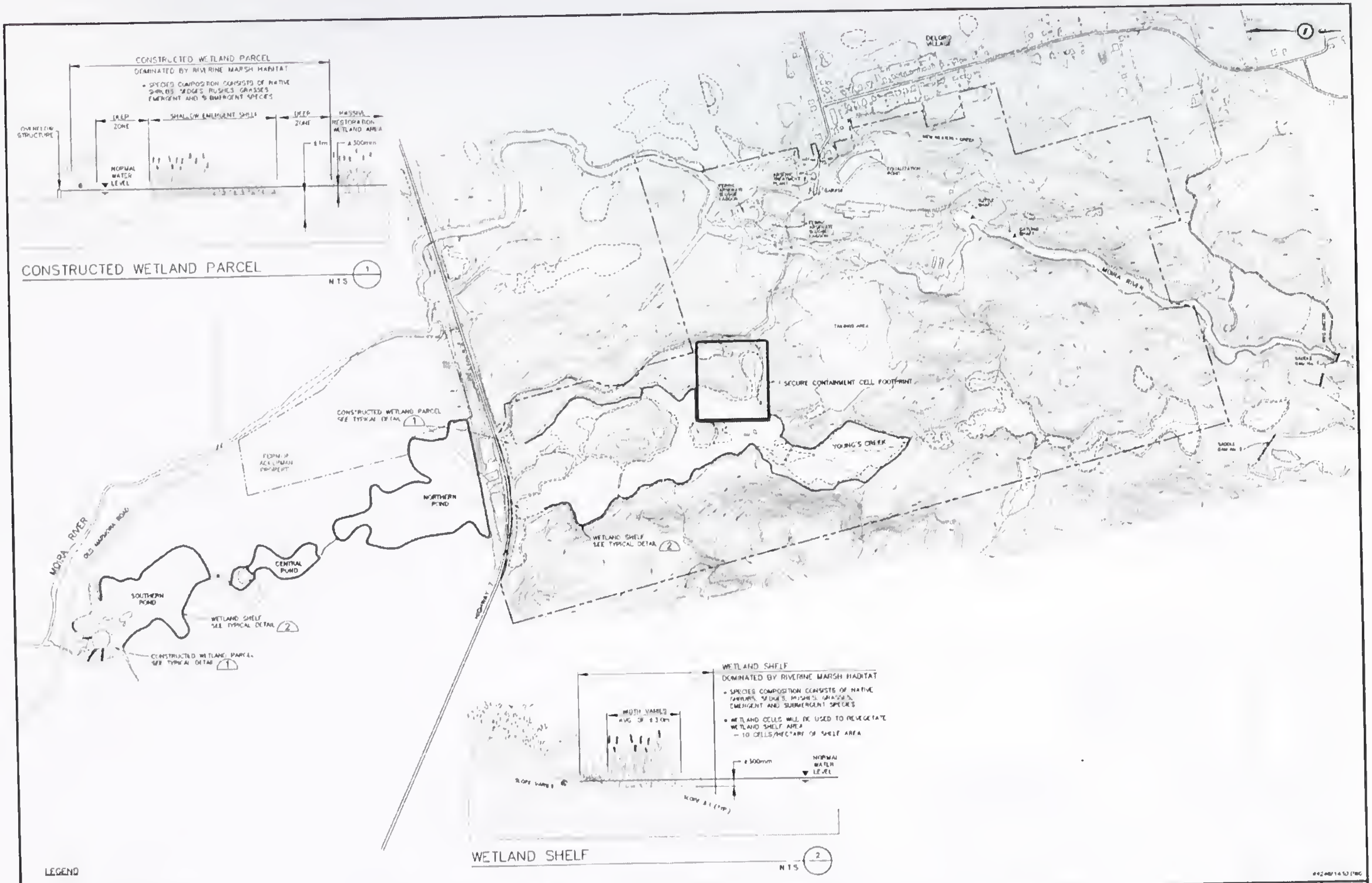
CONSTRUCTED WETLAND PARCEL
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES
OVERFLOW STRUCTURE
DEEP ZONE
SHALLOW EMERGENT SHELF
DEEP ZONE
MASSIVE RESTORATION WETLAND AREA
NORMAL WATER LEVEL
± 1m
± 300mm
CONSTRUCTED WETLAND PARCEL
NTS
1
DELORO VILLAGE
EQUALIZATION POND
GARAGE
MOIRA RIVER
TAILINGS AREA
SECURE CONTAINMENT CELL FOOTPRINT
YOUNG'S CREEK
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
NORTHERN POND
CENTRAL POND
SOUTHERN POND
WETLAND SHELF SEE TYPICAL DETAIL 2
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
WETLAND SHELF SEE TYPICAL DETAIL 2
MOIRA RIVER
OLD MADOC ROAD
HIGHWAY 7
WETLAND SHELF
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES
• WETLAND CELLS WILL BE USED TO REVEGETATE WETLAND SHELF AREA
– 10 CELLS/HECTARE OF SHELF AREA
WIDTH VARIES AVG. OF ± 3.0m
± 300mm
NORMAL WATER LEVEL
SLOPE VARIES
SLOPE 3:1 (TYP.)
WETLAND SHELF
NTS
2

LEGEND

PROPERTY LINE

0 200 400m

SCALE

NOTE
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPH BY NORTHWAY MAP TECHNOLOGY LIMITED (MAY 6, 1992)

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5–4 YOUNG'S CREEK AREA PLAN VIEW
OF COMPREHENSIVE REMEDIATION ALTERNATIVE
DEEP EXCAVATION ONSITE
SHALLOW EXCAVATION OFFSITE

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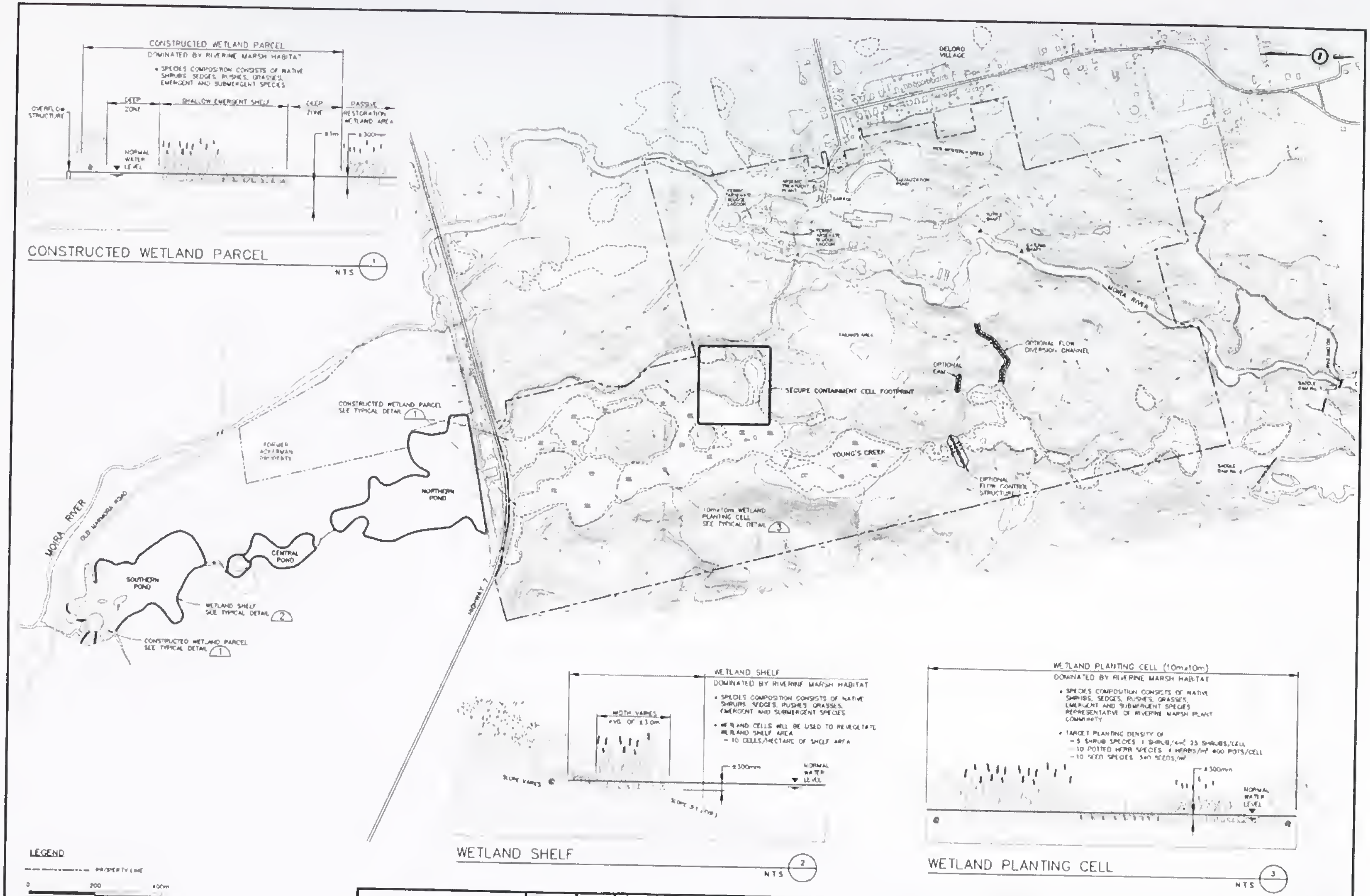
CONSTRUCTED WETLAND PARCEL
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES
OVERFLOW STRUCTURE
DEEP ZONE
SHALLOW EMERGENT SHELF
DEEP ZONE
PASSIVE RESTORATION WETLAND AREA
NORMAL WATER LEVEL
± 300mm
CONSTRUCTED WETLAND PARCEL
NTS
1
DELORO VILLAGE
TAILINGS AREA
OPTIONAL FLOW DIVERSION CHANNEL
OPTIONAL DAM
SECURE CONTAINMENT CELL FOOTPRINT
MOIRA RIVER
YOUNG'S CREEK
OPTIONAL FLOW CONTROL STRUCTURE
SADDLE DAM No. 1
SADDLE DAM No. 2
10m x 10m WETLAND PLANTING CELL SEE TYPICAL DETAIL 3
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
FORMER ACKERMAN PROPERTY
NORTHERN POND
CENTRAL POND
SOUTHERN POND
MOIRA RIVER
OLD MARMORA ROAD
HIGHWAY 7
WETLAND SHELF SEE TYPICAL DETAIL 2
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
WETLAND SHELF
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES
• WETLAND CELLS WILL BE USED TO REVEGETATE WETLAND SHELF AREA
– 10 CELLS/HECTARE OF SHELF AREA
WIDTH VARIES
AVG. OF ±3.0m
SLOPE VARIES
± 300mm
NORMAL WATER LEVEL
WETLAND SHELF
NTS
2
WETLAND PLANTING CELL (10mx10m)
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES, EMERGENT AND SUBMERGENT SPECIES REPRESENTATIVE OF RIVERINE MARSH PLANT COMMUNITY
• TARGET PLANTING DENSITY OF
– 5 SHRUB SPECIES 1 SHRUB/4m² 25 SHRUBS/CELL
– 10 POTTED HERB SPECIES 4 HERBS/m² 400 POTS/CELL
– 10 SEED SPECIES 340 SEEDS/m²
± 300mm
NORMAL WATER LEVEL
WETLAND PLANTING CELL
NTS
3
LEGEND
PROPERTY LINE
0
200
400m
SCALE

NOTE
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPH BY NORTHWAY MAP TECHNOLOGY LIMITED (MAY 6, 1992)

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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5–5 YOUNG'S CREEK AREA PLAN VIEW
OF COMPREHENSIVE REMEDIATION ALTERNATIVE
SHALLOW EXCAVATION ONSITE
DEEP EXCAVATION OFFSITE

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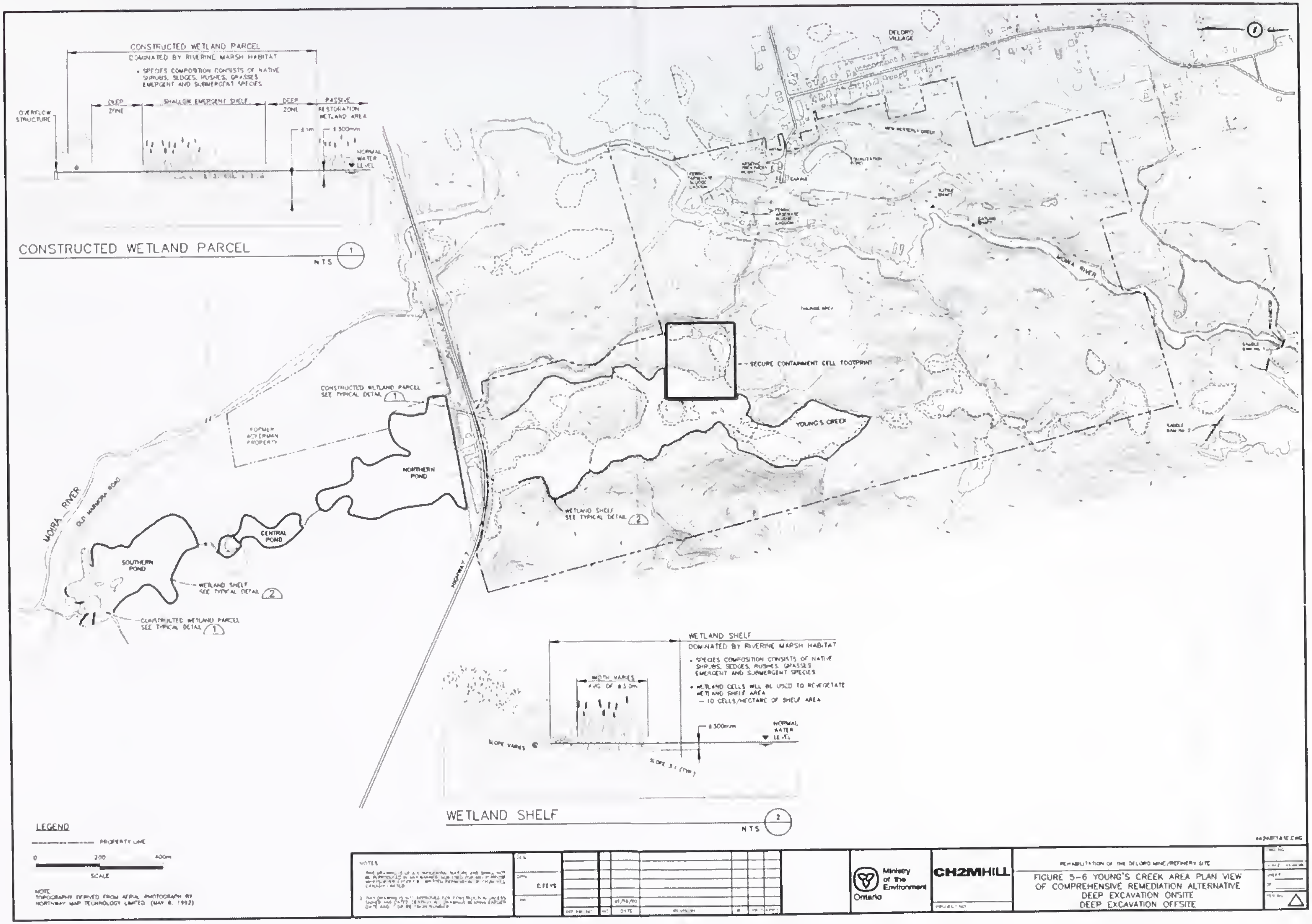
CONSTRUCTED WETLAND PARCEL
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES EMERGENT AND SUBMERGENT SPECIES
OVERFLOW STRUCTURE
DEEP ZONE
SHALLOW EMERGENT SHELF
DEEP ZONE
PASSIVE RESTORATION WETLAND AREA
± 1m
± 300mm
NORMAL WATER LEVEL
CONSTRUCTED WETLAND PARCEL
1
NTS
DELORO VILLAGE
MOIRA RIVER
SECURE CONTAINMENT CELL FOOTPRINT
YOUNG'S CREEK
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
FORMER ACKERMAN PROPERTY
NORTHERN POND
CENTRAL POND
SOUTHERN POND
MOIRA RIVER
OLD MARMORA ROAD
HIGHWAY 7
WETLAND SHELF SEE TYPICAL DETAIL 2
WETLAND SHELF SEE TYPICAL DETAIL 2
CONSTRUCTED WETLAND PARCEL SEE TYPICAL DETAIL 1
WETLAND SHELF
DOMINATED BY RIVERINE MARSH HABITAT
• SPECIES COMPOSITION CONSISTS OF NATIVE SHRUBS, SEDGES, RUSHES, GRASSES EMERGENT AND SUBMERGENT SPECIES
• WETLAND CELLS WILL BE USED TO REVEGETATE WETLAND SHELF AREA
— 10 CELLS/HECTARE OF SHELF AREA
WIDTH VARIES
AVG OF ±3.0m
±300mm
NORMAL WATER LEVEL
SLOPE VARIES
SLOPE 3:1 (TYP.)
WETLAND SHELF
2
NTS
LEGEND
PROPERTY LINE
0
200
400m
SCALE
NOTE
TOPOGRAPHY DERIVED FROM AERIAL PHOTOGRAPH BY NORTHWAY MAP TECHNOLOGY LIMITED (MAY 8, 1992)
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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 5-6 YOUNG'S CREEK AREA PLAN VIEW
OF COMPREHENSIVE REMEDIATION ALTERNATIVE
DEEP EXCAVATION ONSITE
DEEP EXCAVATION OFFSITE

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TABLE 5.4
EVALUATION OF SHORT-LISTED COMPREHENSIVE REMEDIATION ALTERNATIVES

Short-Listed Comprehensive Remediation Alternatives	Detailed Evaluation Criteria														
	Technical Considerations			Costs [3,4]			Social Considerations						Natural Environment			
	Reliability	Compatibility with Existing System	Ease of Implementation	Annual O&M Costs	Capital Costs (millions)	Net Present Value[1] (millions)	Public Acceptance	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character of the Area	Risk to Workers (Health and Safety)	Geochemistry (Improvement)	Terrestrial Habitats (Improvement)	Flood-plain	Fish Habitats (Disruption)
1. Shallow Excavation Onsite, Shallow Excavation Offsite	Fair	Good	Fair	$50,000	$10.17 ($16.42)[2]	$10.82 ($17.07)	Moderate	Low	Low to Moderate	Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Good	Low	Low
2 Deep Excavation Onsite, Shallow Excavation Offsite	Fair to Good	Good	Fair	$65,000	$12.49 ($15.19)	$13.34 ($16.04)	Moderate	Low to Very Low	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Good	Low to Moderate	Low
3 Shallow Excavation Onsite, Deep Excavation Offsite	Fair	Good	Fair	$65,000	$12.81 ($16.36)	$13.66 ($17.21)	Moderate to High	Low	Low to Moderate	Low	Low to Moderate	Low to Moderate	High	Good	Low	Low
4 Deep Excavation Onsite, Deep Excavation Offsite	Good	Good	Fair	$85,000	$14.90 (N/A)[5]	$16.01 (N/A)[5]	Moderate to High	Very Low	Low	Low	Low to Moderate	Low to Moderate	Very High	Good	Moderate	Low

Notes

[1] NPV costs assumed an effective interest rate of 5% and a time horizon of 20 years

[2] Bracketed costs include an optional in-place cap and upstream flow regulation

[3] Expected cost accuracy is +/- 50%.

[4] Costs include GST and a 15% contingency.

[5] Not applicable

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5.4 Detailed Evaluation of Comprehensive Remediation Alternatives

The four remedial alternatives identified in the previous section are evaluated using the four categories of detailed evaluation criteria that were outlined in Section 4. A summary of the detailed evaluation of the short-listed comprehensive remediation alternatives is provided in Table 5.4. Each of the four alternatives are discussed and compared to each other below under each of the detailed evaluation criteria.

5.4.1 Technical Considerations

Reliability

The deep excavation alternative will be more reliable and better than the shallow excavation alternative in reducing contaminant loadings to the Moira River since all contaminated sediments as well as underlying impacted silty clay soils will be excavated and stored in a secure storage cell. The shallow excavation alternative will be fairly reliable in terms of reducing contaminant loadings to the Moira River since the most contaminated sediments will be excavated and stored in a secure storage cell. However, metal concentrations in the underlying deeper organic silty clay will remain that will be above the MOE severe effect level or lowest effect level (SEL or LEL) for sediment. An ecological risk assessment will be required under this alternative to determine whether this residual contamination can be left behind. The screening level concentration for cobalt from the MRS suggests that higher levels of cobalt could remain but not create an adverse impact. Implementing the in-place capping enhancement feature under the shallow excavation alternative will help to reduce the exposure to any residual contamination. The flow regulation option will act to minimize erosion of the placed cap materials during flood events.

All of the alternatives rely on a secure containment cell to dispose of the contaminated sediments. The storage cell for the contaminated sediments can be engineered to ensure minor, if any, future release of contaminants to the environment. The cap would be designed to promote runoff and evapotranspiration, thereby reducing the amount of precipitation that could come into contact with the contaminated sediments in the storage cell. The cap would include a drainage system to intercept any percolating water that does not runoff or is not evapotranspired before it contacts the stored sediments. The liner system would consist of a composite clay and high density polyethylene (HDPE) liner with a leachate collection system as a backup measure to collect any water that does happen to penetrate the cap system. The liquid collected by the leachate collection system would be pumped via forcemain to the onsite treatment plant. The storage cell would be located above the water table to prevent groundwater contact with stored sediments.

Compatibility With Existing System

All of the alternatives will be compatible with existing site conditions, with the possible exception of the alternative requiring deep excavation both onsite and offsite. There is adequate room within the Young's Creek Area to accommodate the secure storage cell for the other three alternatives; however, there may be difficulty in sizing an adequate storage cell within the Young's Creek Area for the deep excavation alternative for both the onsite and offsite portions. The deep excavation alternative relies on the potential to place the less contaminated sediments from the offsite portion of Young's Creek in the Tailings Area.

The existing onsite wastewater treatment system can be utilized to treat any contaminated water collected by the leachate collection system of the secure containment cell. As the flow rate for leachate is expected to be low, the capacity of the treatment plant is not anticipated to pose a problem.

Ease of Implementation

In terms of implementation, the required contractors and materials required are readily available for all of the alternatives. However, there will be some challenges that will be common to all of the alternatives. Significant dewatering efforts will be required prior to and during the excavation work. Excavation work will be limited to the wintertime. The trial excavation of frozen Young's Creek sediments completed in March 1999 indicated that it is feasible to excavate materials in the winter, while the ground is frozen. The ice and frost cover offers a stable work platform if water under the ice is pumped out during freeze up. In addition, access and water management conditions will be best during the colder months.

Water management will be required throughout the project that involves controlling flows in Young's Creek during the excavation and storage of the materials. Dewatering of the sediments will be required prior to disposal. Blasting and rock removal will be required to obtain enough area for the containment cell. Approvals that will be required for all alternatives include MOE approvals for the secure storage cell and MNR and Conservation Authority approvals for the work in and modification of the floodplain.

In terms of differences between the alternatives, it is apparent that the deep excavation options will be more difficult to implement than the shallow excavation options.

5.4.2 Costs

The capital and construction costs, the annual operation and maintenance costs, and the net present value costs associated with each alternative are summarized in Appendix B. The breakdown of the various components of the total cost associated with each alternative is detailed in Appendix B. In addition, the major assumptions used in the cost opinions are stated in Appendix B. Because of the uncertainty in design requirements at this conceptual design stage, all costs provided should be considered as "cost opinions" at this stage to assist the MOE in choosing among the comprehensive remediation alternatives.

As expected, the alternative requiring shallow excavation both onsite and offsite had the lowest capital costs at $10,169,000 (excluding the capping option at $5,160,000 and flow regulation option at $525,000), annual operation and maintenance cost at $50,000, and a net present value cost at $10,819,000 (excluding the enhancement options). However, when the enhancement options were included in the costs, all of the alternatives had similar costs. For example, the net present value costs ranged between $16,038,000 and $17,207,000 for the four alternatives when the enhancement options were included in the costs. (It is noted that the alternative requiring deep excavation both onsite and offsite would not require implementation of the enhancement options, since all contaminated materials would be removed from the creek basin). Considering the level of accuracy inherent in the cost estimates at this conceptual stage (+/- 50%), and the relatively small range in costs between alternatives, cost will not be a major factor in selecting the preferred alternative.

The net present value calculations were based on an assumed effective interest rate of 5 percent and a planning horizon of 20 years. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

5.4.3 Social Considerations

Public Acceptance

Since each of the alternatives require the removal of contaminated sediments and the rehabilitation of the creek, it is likely that each of the options would receive general public acceptance as they will result in an overall improvement to the environmental conditions in the area. However, there may be possible opposition to siting the secure storage cell onsite for all of the alternatives.

In addition, the three alternatives that involve shallow excavation of the most contaminated upper sediments will rely on the results of an ecological risk assessment. The risk assessment is required to determine if the risks posed to ecological receptors by the impacted silty clay soil underlying the contaminated sediment is acceptable. The use of the risk assessment approach to justify leaving the lesser contaminated underlying soils in place may not be readily accepted by the public. It would be expected that the deep excavation alternative will receive more support from the public than the shallow excavation alternative.

Risk to Public

All of the alternatives will result in a reduction of risk to public health and safety due to exposure and release of contaminants. The deep excavation alternative will be the most certain in terms of long term reduction in risk to public health and safety. Periodic monitoring of the secure containment cell will be required to confirm performance and implement contingency measures if required.

All of the alternatives have the potential to pose some risk to the public during the implementation stage. The primary risk would be exposure to arsenic and metal contamination via inhalation of dusts that could occur during the dewatering, consolidation, and placement of sediments in the secure containment cell. A properly developed and executed health and safety plan will be required to mitigate this risk.

Constraint for Recreational Use

Recreational use is only a consideration for the offsite portion since the onsite portion will be restricted using signage and fencing. The deep excavation option will result in no limitations to recreational activities. The increased depths in water could create improved fishing opportunities.

The three alternatives that involve shallow excavation of contaminated sediments may result in some limitations to recreational activities due to residual contamination. Under these alternatives, an ecological risk assessment should be performed to quantify the impacts of the residual contamination on the sport fishing population.

During implementation of any of the alternatives, recreational use would be impacted during the excavation and restoration activities.

Negative Impact to Private Properties

The two alternatives that involve the deep excavation of contaminated sediments and underlying soil in the offsite portion of Young's Creek will be the most effective at reducing the impacts due to the contaminated sediments. The deep excavation option will definitely increase the pond depths in the offsite portion of Young's Creek, but this should not significantly affect the property owner's use and enjoyment of this property in the long term.

The two alternatives that involve shallow excavation of the contaminated sediments in the offsite portion of Young's Creek will obviously result in an improvement to sediment and water quality; however, some residual contamination will remain. The alternatives requiring deep excavation will likely receive more support from the owners of the offsite portion of the creek.

All of the alternatives will result in significant disruption to the owners of the offsite portion of Young's Creek due to the required pond dewatering and excavation work that would occur.

Visual Character of the Area

All of the alternatives will result in a significant improvement to the visual character of the area, particularly in the onsite portion of Young's Creek. Removal of the red mud sediments and the restoration of the creek will be the most noticeable visual change.

Under all of the alternatives, the visual appearance of the offsite portion of Young's Creek will not noticeably change following remedial and creek restoration work. The two alternatives that involve the full depth excavation of contaminated sediments in the onsite portion of Young's Creek will result in a change from a braided stream to deeper ponded areas.

The construction of the secure storage cell will have some visual impact under all of the alternatives. This impact is expected to be minor due to the hilly nature of the area and the limited visibility from the property line. The final elevation of the proposed storage cell would be in line with the surrounding topography.

Risk to Workers

Risks to workers would be similar under all of the alternatives. These risks would include heavy machinery hazards and exposure to arsenic and metals during the dewatering, consolidation, and placement of sediments in the secure containment cell. A properly developed and executed health and safety plan would be required to mitigate these risks.

5.4.4 Natural Environment

Geochemistry

All of the alternatives will result in an improvement to surface water quality. The largest immediate improvement in surface water quality will occur following the alternative involving the deep excavation of contaminated sediments and impacted underlying soil both onsite and offsite. Under the other three alternatives, surface water quality will improve over time as natural sedimentation reduces exposure to any residual contamination. The creek rehabilitation measures will improve surface water quality. The use of in-place capping as an enhancement feature would also act to improve surface water quality.

Terrestrial Habitats

All of the alternatives will result in a significant improvement to terrestrial habitats. This is because all of the alternatives include the removal of the highly contaminated red mud sediment from the onsite portion of Young's Creek, where there is currently no vegetation growing. Removing these highly contaminated sediments and completing creek rehabilitation measures will improve conditions for establishing more vegetation and thus terrestrial habitats over the long term.

Floodplain

The two alternatives that involve deep excavation in the onsite portion of Young's Creek will have an effect on the floodplain characteristics. The onsite portion of Young's Creek, which is currently a braided stream, will be transformed to a deeper ponded area. Minimal changes to the floodplain will result in the offsite portion of Young's Creek under all of the alternatives.

All of the alternatives require construction of a portion of the secure containment cell within the floodplain. The containment cell is expected to have a minimal impact on the characteristics of the floodplain due to its relatively small size compared to the wide floodplain.

Fish Habitats

Currently, the toxicity impacts are low enough to permit survival of a diversified fish community in the Moira River system. Removal of contaminated sediment will however act to improve water quality for fish habitats. Obviously, the alternative requiring deep excavation of all contaminated sediments will result in the greatest improvement.

5.4.5 Selection of Recommended Remediation Alternative

The recommended remediation alternative to address contamination in the Young's Creek Area, based on the detailed evaluation and comparison of the short-listed alternatives is:

Deep Excavation Onsite – Shallow Excavation Offsite

Some of the key factors considered in making this selection include the following:

- Under this alternative, the quality of soil remaining in the Young's Creek Area following implementation of this alternative would be equal to or better than the sediment quality downstream from the Deloro site in the Moira River and Moira and Stoco Lakes. The Phase II Moira River Study Report (Golder, 2001) concluded that there were no obvious adverse effects observed in benthic invertebrates or fish populations due to sediment quality that did not meet the MOE SEL. In this study report, it is noted that arsenic concentrations above the MOE SEL were measured in the Moira River, Moira Lake, and

Stoco Lake. Remediating the Young's Creek Area to the same sediment quality as these downstream water bodies, as opposed to the SEL, is considered a pragmatic approach. This approach could be further optimized should the cobalt criteria developed in the MRS be confirmed as a suitable cleanup criterion.

- This alternative can reliably reduce the potential for contaminant loading to the Moira River.
- The levels of metal contamination in the silty clay soil underlying the contaminated sediments, in the onsite portion of Young's Creek, were well above the SEL in most cases. In fact, the soils underlying the contaminated sediments in the onsite portion of Young's Creek had higher metal concentrations than the shallower most contaminated sediments in the offsite portion of Young's Creek. It is hard to justify leaving the impacted underlying soil in the onsite portions of the creek while the much less contaminated sediments were being removed in the offsite portions of the creek. Therefore, the alternative that involved shallow excavation onsite and deep excavation offsite was eliminated as a viable option.
- This alternative is as compatible with existing site conditions and treatment systems as the two options that require shallow excavation in the onsite portion of Young's Creek. The alternative requiring deep excavation both onsite and offsite is not as compatible with existing site conditions due to the limited area in the Young's Creek Area for a secure storage cell with adequate capacity.
- All of the alternatives present similar challenges with respect to ease of implementation.
- The accuracy of the cost estimates at this conceptual stage is estimated at +/- 50%. Since all of the alternatives have capital and construction costs within 50 percent of one another, capital cost was not a major determining factor in which alternative is selected.
- Annual operation and maintenance costs associated with all of the alternatives are primarily associated with the secure storage cell. Since all alternatives require the onsite secure storage cell, operation and maintenance costs for all alternatives are expected to be similar. Since both capital and operation and maintenance costs are similar, net present value costs for all alternatives are also similar.
- In terms of public acceptance, we expect that the recommended alternative will be better received than the two alternatives requiring only shallow excavation of onsite sediments.
- In terms of risk to public health and safety, the recommended alternative will be more protective than the two alternatives requiring only shallow excavation of onsite sediments.
- All of the alternatives ranked similarly in terms of recreational use opportunities and impacts to private property.
- All of the alternatives provided a similar improvement in terms of the visual improvement of the creek basin and improvements to fish and terrestrial habitats, particularly the onsite portion. All of the alternatives required a secure storage cell, which could be viewed as a negative visual impact.

- This alternative will result in an improvement in water quality. Water quality in Young's Creek will be similar to the Moira River, providing that releases from the Tailings Area are effectively contained in the future.
- Storage in the Tailings Area is not required under this alternative, eliminating the uncertainty that would exist under the deep excavation alternative for both the onsite and offsite portions of the creek.

6. Recommended Remediation Alternative

The various components forming this comprehensive remediation alternative are provided in Figure 5-4 and have been discussed separately in some detail previously. Provided below, these various components are assembled and described as a single comprehensive remediation alternative. In addition, cost details associated with the preferred alternative are further developed. Finally, recommendations outlining any data gaps and/or additional work that should be completed prior to developing a detailed design for the recommended alternative design are discussed.

6.1 Key Components of the Recommended Alternative

6.1.1 Site Preparation

Prior to commencing the remedial work, site preparation work will be completed that includes mobilization of equipment (excavators, trucks, dewatering pumps and equipment, site trailers), construction of access roads where required, and establishment of temporary services. It is proposed to complete the excavation work in the "dry", therefore any ponded water will need to be drained prior to excavation. Sediment control measures will need to be implemented to minimize the transport of disturbed sediments to the Moira River.

6.1.2 Excavation

For the onsite portion of Young's Creek, this alternative consists of excavating the upper most highly contaminated organic and red mud sediments as well as the lesser contaminated underlying soils. The resulting removal depth for the onsite sediments ranges between 1.0 and 1.5 metres. For the offsite portion of Young's Creek, only the upper most impacted sediments (approximately the upper 0.5 metres) would be excavated and any marginally impacted sediments would be left. These marginally contaminated sediments, while exceeding the SEL, would have metal contaminant concentrations similar to those existing in the Moira River as well as in Moira and Stoco Lakes.

It is anticipated that the bulk of the excavation work can be conducted during the winter months. The trial excavation of frozen Young's Creek sediments by CH2M HILL in March 1999 indicated that it is feasible to excavate materials in the winter when the ground is frozen. The ice and frost cover offers a stable work platform, if water under the ice is pumped out during freeze up. In addition, access and water management conditions will be best during the colder months.

Water management will be required throughout the project that involves controlling flows in Young's Creek during the excavation and storage of the materials. Dewatering of the sediments will be required prior to disposal.

The excavated sediments would be moved to a staging area for dewatering and consolidation prior to disposal. The estimated volume of contaminated sediments requiring excavation is approximately 199,000 m^3 from the onsite portion, and 60,000 m^3 from the offsite portion resulting in a total of approximately 259,000 m^3. These sediments would be disposed of in a secure containment cell that would be located in an area adjacent to the Tailing Area as shown in Figure 5-4. The containment cell for the contaminated sediments can be engineered to ensure minor, if any, future release of contaminants to the environment.

6.1.3 Secure Onsite Containment Cell

The containment cell would have engineered cap and liner systems that would be designed to prevent contaminant releases. The cap would consist of a vegetated cover, 150 mm of topsoil, 1000 mm of compacted fill, 300 mm cap drainage layer, and a geosynthetic clay liner to prevent infiltration of surface water. The cap would be designed to promote runoff and evapotranspiration, thereby reducing the amount of precipitation that could come into contact with the contaminated sediments in the storage cell. The cap includes a drainage system to intercept any percolating water that does not runoff or is not evapotranspired before it contacts the stored sediments. This clean infiltrating water collected in the cap system would be directed to Young's Creek.

The liner system would consist of a 1000-mm thick clay liner and a high density polyethylene (HDPE) liner with a leachate collection system as a backup measure to collect any water that does happen to penetrate the cap system. The liquid collected by the leachate collection system would be collected in sumps and pumped via forcemain to the onsite treatment plant. The storage cell would be located above the water table to prevent groundwater contact with stored sediments.

6.1.4 Creek Rehabilitation

A majority of the remediated area would be restored allowing the local seed bed to regenerate the wetland plant community naturally. It is expected that if appropriate hydrological conditions are established that are relatively consistent with the existing wetlands it will provide an ideal environment for the utilization of this restoration method. In addition, more intensive planting using local seed material and potted plant stock is suggested at select locations within the creek corridor. Water quality improvements associated with wetlands would be the primary benefit derived from quick wetland establishment. To hasten the establishment of the wetland, two wetland parcels and a perimeter wetland shelf will be constructed as shown in Figure 5-4.

Wetland planting cells throughout the excavated area are not applicable under the recommended remediation alternative due to the water depth that will result following excavation. As stated in Section 5.2.5, wetland environments will be restricted to the littoral zones that will exist along the perimeter of the creek once the wetland shelf is created. Opportunities for the restoration of the dominant riverine marsh habitat will be limited to areas with water depths of approximately 300 mm. The excavation of contaminated sediments will result in water depths of at least 1000 mm and these excavated areas will be continuously submerged.

The wetland parcels will be installed at two strategic locations. One wetland parcel will be installed at the southern extent of the creek upstream of Highway 7. The other wetland parcel will be installed at the lower end of the Southern Pond, prior to the point of discharge at the Moira River. The wetland parcels would provide some level of treatment and filtration prior to the discharge of creek water into the Southern Pond and the Moira River. The construction of the wetland parcels will involve placement of fill material in the two locations to create the appropriate hydrology to establish a shallow emergent shelf. Planting of native shrubs, sedges, rushes, grasses, and emergent/submergent species, by both seed and transplanting would be completed.

Construction of the wetland shelf would consist of grading to provide littoral zones around the perimeter of the ponded areas. The shelf would be graded to provide an optimum water depth to support a diverse wetland community associated with the dominant riverine marsh habitat. The shelf would be continuous around the perimeter and have varying widths based on an aesthetic requirement. A 75-100 mm depth of topsoil would be required on top of the wetland shelf to provide an ideal environment for seed germination and subsequent root development. The shelf would provide limited treatment potential but instead would stabilize the soil and provide an aesthetic function. A series of wetland planting cells would be initiated at strategic locations throughout the wetland perimeter shelf. The wetland planting cell is approximately a 100 m^2 area within which a specific plant mix is established that consists of seed and potted plant stock. Since the shelf is approximately 3-m wide, each planting cell installed around the perimeter will be 33-m in length. The wetland planting cells replace the seed bed contained in the upper 500 mm of stripped soil and the substrate seed bed that was covered with 300 mm of imported soil.

6.2 Operation and Maintenance Requirements

Operation and maintenance efforts under this alternative will be associated primarily with the onsite secure containment cell. The pumps, controls, and piping associated with the leachate collection system will require monitoring and periodic maintenance. There will be hydro costs associated with the operation of the collection pumps that transfer the collected leachate to the treatment facility. The treatment costs associated with the leachate collected from the containment cell have been included in the Industrial Area costs. These costs have not been duplicated in this evaluation. It is anticipated that the volume of leachate requiring treatment from the Young's Creek Area containment cell will be small relative to the capacity of the treatment plant (<10 percent). The leachate collection system will require periodic flushing and cleaning. Periodic maintenance of the cap will be required to repair any erosion damage. A detailed operations and maintenance plan should be established for the containment cell following implementation of this alternative.

Regular environmental performance monitoring will be required. Monitoring wells should be installed at key selected locations in the vicinity of the containment cell. Semi-annual monitoring of groundwater both upgradient and downgradient of the containment cell is recommended. Monitoring of the level of liquid above the liner should be conducted to assess the degree of leachate mounding. Semi-annual inspections of the storage cell cover should be completed to identify erosion problems, slope stability, and areas of vegetative stress.

6.3 Cost Opinion

A breakdown of the estimated cost associated with this alternative is provided in Appendix B and is summarized in Table 6.1. The major assumptions used in making this cost estimate are provided in Appendix B. The costing in Appendix B has been completed at the conceptual design level and should be considered as a "cost opinion" to assist in selecting a preferred alternative. Costs can further be defined, once the preferred conceptual alternative has been selected and a detailed design and approach is developed.

The net present value costs below are the sum of the capital cost and the net present value of the operation and maintenance costs. The annual operation and maintenance costs have been transformed to a net present value assuming an effective interest rate of 5 percent and a planning horizon of 20 years. The effective interest rate includes inflationary effects. It should be noted that operation and maintenance effort and costs will be required beyond the 20 year horizon. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

TABLE 6.1
COST BREAKDOWN TO IMPLEMENT THE RECOMMENDED REMEDIATION ALTERNATIVE (EXCLUDING ENHANCEMENTS)

Cost Item	Estimated Cost
Capital Cost Items	
1. Site Preparation	$410,000
2. Water Diversion	$380,000
3. Excavation and Placement of Sediments	$3,548,000
4. Secure Onsite Containment Cell	$4,600,000
5. Leachate Collection and Transfer	$ 830,000
6. Engineered Creek Rehabilitation	$ 580,000
7. Access Roads for Offsite Cleanup	$ 980,000
8. Overhead, Insurance and Bonds	$1,159,000
Total Capital Cost	**$12,487,000**
Operation and Maintenance Cost Items (Annual)	
1. Landfill Cap	$20,000
2. Leachate Collection System	$15,000
3. Environmental Performance Monitoring	$30,000
Total Annual O&M Costs	**$65,000**
Net Present Value of O&M Costs	**$850,000**
Net Present Value of Capital and O&M Costs	**$13,337,000**

6.4 Data Gaps

The potential for using the lesser contaminated silty clay soils from the onsite portion of Young's Creek as part of the clay cap on the Tailings Area should be investigated further. Although, placing these sediments in the Tailings Area is not required under this alternative, significant cost reductions could be realized if this was feasible.

It should be confirmed with the MNR and Conservation Authority that the approach taken under this alternative to restore the Young's Creek Area following excavation is acceptable.

It should also be confirmed with the MNR and Conservation Authority that the required permits can be obtained to implement this alternative. Permission will also be required from the property owners of the offsite portion of Young's Creek to implement the recommended alternative.

The Site Specific Risk Assessment planned for the site, specifically the ecological risk assessment component, should be completed to confirm that the deeper less contaminated silty clay soils in the offsite portion of Young's Creek can remain without posing an unacceptable risk to ecological receptors. However, as stated in this report, previous studies in the Moira River, Moira Lake, and Stoco Lake have concluded that the levels of contamination that would remain in the sediments have not adversely impacted benthic invertebrates or fish populations.

It is also recommended that an ecological risk assessment be completed for the onsite portion of Young's Creek to further investigate and quantify the risk associated with leaving the deeper less contaminated underlying silty clay soil onsite. Results of the Moira River Study suggest that there is no measurable impact from sediment contamination considerably above the SEL, which, if applicable to the onsite silty clay soils, could lead to substantial cost savings by implementing Scenario 1 versus Scenario 2.

Available contaminant information in the Young's Creek Area indicates that contamination is focused in shallow sediment and silty clay soil. The absence of significant impacts on groundwater in the Young's Creek Area should be confirmed as part of the Closure Plan development.

Floodplain modelling should be conducted to confirm that the proposed containment cell and other changes to the floodplain does not create flooding problems in the vicinity of Highway 7. However, it is not anticipated that the proposed containment cell will cause flooding problems.

The release of contaminants from the Tailings Area must be adequately addressed prior to undertaking remedial efforts in the Young's Creek Area.

6.5 Summary

The recommended remediation alternative to address contamination in the Young's Creek Area is to excavate and dispose of the contaminated sediments in an onsite secure containment cell. For the onsite portion of Young's Creek, the excavation would include both the highly contaminated upper organic red mud sediments and the lower silty clay soil. For the offsite portion of Young's Creek the excavation would include the upper organic contaminated sediments. Following the excavation of contaminated sediments, creek restoration activities would be completed that include the construction of a perimeter wetland shelf and the installation of two strategically located wetland parcels.

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